RAILWAY SURVEY AND PERMANENT WAY ENGINEER'S POCKET BOOK

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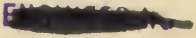

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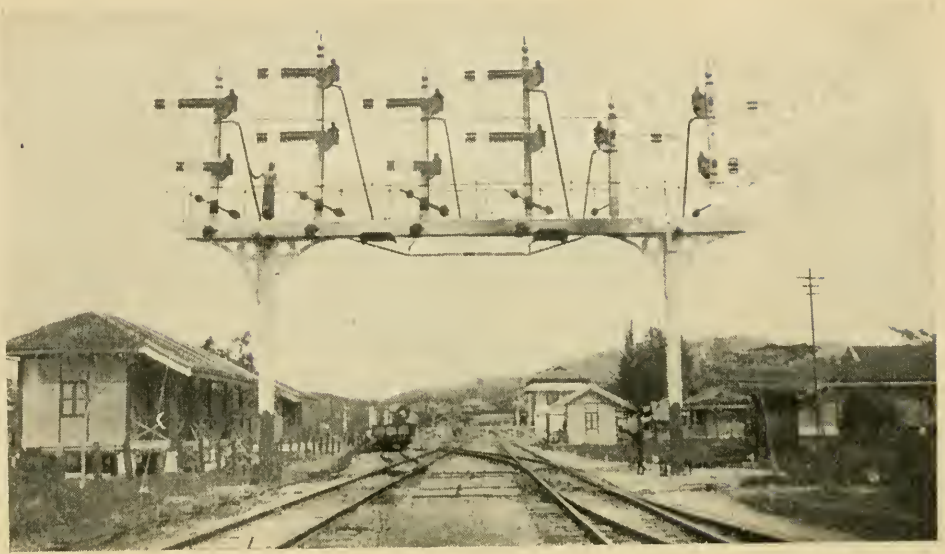

SIGNAL GANTRY WITH LEVEL CROSSING GATES

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Preface to the Second Edition.

The success attained in the first edition of the Signal and Permanent Way Engineer's Pocket Book has been so marked that the Publishers have pleasure in bringing out a second edition, and it will be noted that several additional features have been included.

The Publishers would like to state, however, that it is very difficult to bring within the limits of a Pocket Book detailed methods of operation with regard to the Construction of Permanent Way and installing of Railway Signalling, as this must necessarily depend upon the exigencies of local circumstances that obtain in each specific instance.

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DEVELOPMENT OF FIXED SIGNALS.

In the earliest days of the railways the trains, which were few in number, were run according to time-table, with the additional protection of the flag or lamp signals exhibited by the policemen whose duty it was to patrol the line and protect the various stations and junctions.

As the trains ran strictly to schedule, the drivers always took it for granted they had a clear road unless they had a "Danger" signal shown them by the policeman or station staff.

As traffic developed, hand signals were superseded by fixed indications and lamps on posts at the more important stations, until in course of time these fixed signals came into general use. The day indications in the early stages were numerous and of curious design.

At the opening of the G.W.R. in 1838 the "ball" and "kite" signals, shown on diagrams 1 and 2, were in use. The former consisted simply of a post, to the top of which a ball was hoisted to indicate "safety," an ordinary stable lantern being used at night instead of the ball. The "kite" signal consisted of a light iron frame fixed on the top of a post with a movable canvas screen mounted on rings. By means of a double string, the canvas could be spread out like a curtain on either side to indicate "Danger" or "Caution," or reefed entirely to indicate "Safety." On some other lines flags hoisted on poles were used, while on the Eastern Counties Railway baskets on poles were utilized. In the course of a few years, however, these makeshift appliances generally gave place to the better known movable crossbar type of signal.

Illustrations 3 and 4 represent an early form of this type of signal, which consisted of a disc (4 feet in diameter mounted on the top of a movable post with a crossbar 8 feet long and 1 ft. wide) fixed at right angles below it. The presentation of the crossbar to the driver indicated "Danger," and the disc denoted "Safety." Although not shown in the illustration the disc was usually surmounted by a lamp furnished with white and red lenses to correspond with the daylight indications.

At Branch line junctions double arms and double discs were sometimes provided to govern the Branch line trains (Nos. 5 and 6). On the G.W.R. down line signals were subsequently distinguished by end pieces (Nos. 7 and 8), and level crossing signals were provided with double end pieces to indicate danger to Up and Down trains when the gates were across the railway.

The practice was for the "Danger" signal to be exhibited after the passing of a train for a specified number of minutes according to the distance to the next station.

In some cases the arrow signals (Nos. 13 and 14) were also used. The red "Danger" side was presented for five minutes after the passage of a train, then the green

" Caution " side was shown, and after five minutes more the signal was turned " edge on."

In 1842 the " Semaphore " type of signal (Nos. 9 and 10)—now in universal use—was introduced on the Croydon Railway, and very rapidly adopted. It is interesting to note that soon after it came into general use and until the 'seventies it was worked as a three-position signal, an intermediate or " Caution " position being given in addition to the " Danger " and " All right " indications illustrated. A white light at night was the universal " all right " indication until about 1890, when the green light was made standard.

Electrical arm and light repeaters appear to have been introduced in the 'seventies.

INTERLOCKING OF POINTS AND SIGNALS.

The necessity for working switches and signals from a central position gradually became felt, and the "concentration " of signal and point levers at important stations was taken in hand prior to 1850. It was not until 1856, however, that the first interlocking frame preventing the contradictory movement of signals or points was constructed by the late Mr. Saxby and installed at Bricklayers Arms' Junction. This was a great advance, and was speedily followed up on all the leading railways, although it was not until 1889 that the adoption of interlocking was made compulsory by Parliament.

Facing point locks and bars were introduced in the late 'sixties, and facing point detectors added some ten years afterwards

EVOLUTION OF BLOCK TELEGRAPH.

The first actual working electric telegraph of any length was Cook & Wheatstone's installation between Paddington and West Drayton on the G.W.R. opened in 1838, and soon afterwards extended to Slough. Mr. Edwin Clark subsequently modified Mr. Cook's method and introduced on the North Western Railway that mode of signalling known as " The Block System."

Mr. (afterwards Sir) W. F. Cook's system was actually applied on ths Norfolk Railway in 1844, and on the G.W.R. in 1850. In 1851 Mr. Edward Tyer designed the instruments known by the name of " Tyer Train Signalling Telegraphs," employing only one line wire. These instruments have been improved from time to time to meet modern conditions and are now in almost universal use throughout the world.

As far back as 1870 block working was firmly established on the main routes of the principal railways, and was made obligatory on passenger lines by the Regulations of Railways Act of 1889.

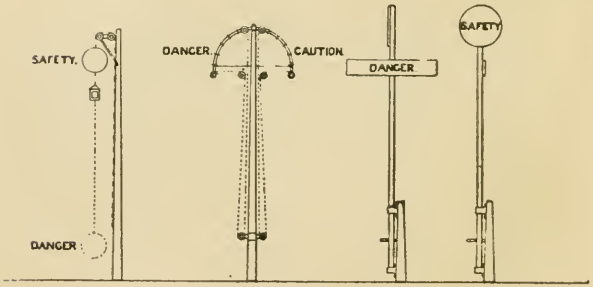
WORKING OF SINGLE LINES.

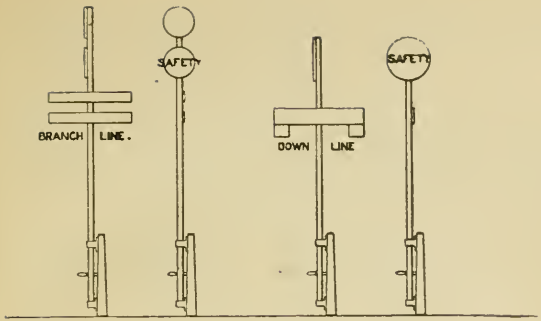
On single lines the "one engine in steam," and the "token" principles were adopted at a very early period, and the block telegraph was also subsequently utilized in conjunction with telegraphic "crossing orders" to the trainmen.

The introduction of tickets to be used in combination with the Train Staff and Block Telegraph was subsequently found to answer the requirements on Branch lines with infrequent train services. Difficulty was, however, experienced on busy single lines until the advent of the Tyer's Tablet system in the 'seventies, and later the electric train staff and key token systems. Experience showed that the maximum service possible under the staff and Ticket system could be increased by 25 per cent. with the greater facilities available under the Electric Tablet and other token systems.

During the last ten years immense strides have been made in railway signalling by the introduction of "power" installations of various types; automatic and semi-automatic signalling installations, and the very general application of track circuiting.

On two leading lines (the G.W.R. and the N.E.R.) audible signalling installations—combined in the G.W. system with Automatic Train Control—are in operation.





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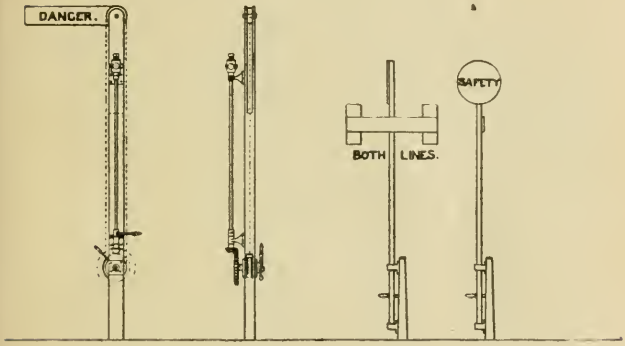

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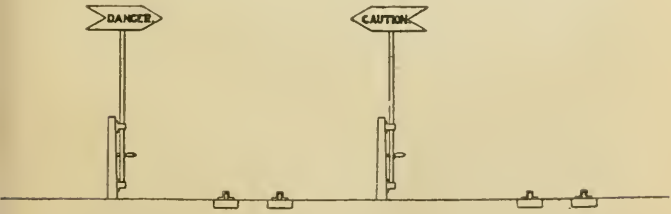

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BOARD OF TRADE REQUIREMENTS IN REGARD TO SIGNALLING OF RAILWAYS.

DOCUMENTS.

Diagrams of the Signalling arrangements at all Junctions, Stations, Block Posts, etc., have to be forwarded to the Railway Department, Board of Trade, previous to the second notice of the intention to open a railway being given.

BLOCK TELEGRAPH.

Block Telegraph Apparatus to be universally provided, except in the case of single lines worked by one engine under steam, or two or more coupled together carrying a train token.

SIGNALS.

Home and Distant Signals for each direction to be fixed at all block posts with extra signals at stations for such dock or bay lines as are used either for the arrival or departure of trains. Starting signals for each direction to be fixed at all Passenger Stations which are also block posts. On Passenger lines all crossover roads and all connections for Goods or Mineral lines and sidings to be protected by Home and Distant Signals.

Signals may be dispensed with on Single Lines under the following conditions :—

(*a*) At all stations and siding connections upon a line worked by one engine only, or two engines coupled together, carrying a token and when all points are locked by such token.

(*b*) At any intermediate siding connection upon a line worked under the train staff and ticket system, or under the electric staff or tablet system, where the points are locked by the staff or tablet.

(*c*) At intermediate stations, which are not staff or tablet stations upon a line worked under the Electric Staff or Tablet system, sidings, if any, being locked as in (*b*).

The signals at junctions to be on separate posts or brackets, and the signals at stations, when there is more than one arm on one side of a post, to be made to apply, the first or upper arm to the line on the left, the second arm to the line next in order from the left, and so on ; but in cases where the main or more important line is not the one on the left, separate signal posts to be provided, or the arms to be on brackets. Distant signals to be distinguished by notches cut out of the ends of the arms, and to be controlled by Home or Starting Signals for the same direction when on the same post. A Distant Signal arm must not be placed above a Home or Starting Signal arm on the same post for trains going in the same direction.

In the case of sidings either a disc signal to be provided or a low short arm and a small signal light, distinguishable from the arms or lights used for running signals. Every signal arm to be so weighted as to fly to and remain at danger on the breaking at any point of the connections between the arm and lever working it.

The lights for running signals to be green for all right, and red for danger; the back lights (visible only when the ignals are at danger) to be white. The back lights of the signal lamps to be made as small as possible, having regard to efficiency, and when the front lights are visible to the signalman in his box, no back lights to be provided. If from any unavoidable cause the arm and light of any signal cannot be readily seen by the signalman, they must as a rule be repeated in the box.

In the case of disc or dwarf signals, a white light to be used in lieu of a red one, except where the signals control movements from sidings to main lines, or in and out of running loops.

POINTS.

Facing points to be placed as near as practicable to the levers by which they are worked or bolted. The limit of distance from levers working points to be 200 yards in the case of facing points, or 250 yards on condition that in addition to the detection of switch blades the position of the bolt lock is also efficiently detected. In power-worked facing points the distance may be 300 yards from the box; 300 yards is the maximum distance allowed in the case of trailing points on the main line, or safety points of goods lines and sidings.

In order to ensure that facing points are in their proper position before signals are lowered, means should be provided for detecting the position of the switches. To prevent facing points being shifted whilst a train is passing over them they must be fitted with facing point locks and locking bars, or some other device for the same purpose. The length of the locking bars to exceed the greatest wheel base between any two pairs of wheels of the vehicles in use on the line, and the stock rails to be tied to gauge with iron or steel ties. All points, whether facing or trailing, to be worked or bolted by rods and not by wires and to be fitted with two connecting rods.

INTERLOCKING.

The levers by which points and signals are worked to be interlocked and, as a rule, brought close together into the position most convenient for the person working them in a signal box or on a properly constructed stage. The signal box to be commodious and to be supplied with a clock and with a separate block instrument for signalling

trains on each line of rails. The point levers and signal levers to be so placed in the box that the signalman when working them shall have the best possible view of the railway, and the box itself to be so situated as to enable the signalman to see the arms and lights of signals and the working of the points. The fixed lights in the signal box to be screened off so as not to be mistakable for the signals exhibited to control the running of trains.

The interlocking to be so arranged that the signalman shall be unable to lower a signal for the approach of a train until after he has set the points in the proper position for it to pass; that it shall not be possible for him to exhibit at the same moment any two signals that can lead to a collision between two trains; and that after having lowered the signals to allow a train to pass, he shall not be able to move any points connected with, or leading to, the line on which the train is moving. Points also, if possible, to be so interlocked as to avoid the risk of a collision.

Home or starting signals next in advance of trailing points when lowered to lock such points in either position, unless such locking will unduly interfere with the traffic.

A distant signal must not be capable of being lowered unless the home and starting signals in advance of it have been lowered. Adequate means to be provided when necessary for reminding the signalman of vehicles which are standing within his control.

LEVEL CROSSINGS.

At all level crossings of public roads the gates to be so constructed that they may be closed either across the railway or across the road at each side of the crossing, and a lodge or, in the case of a station, a gatekeeper's box to be provided unless the gates are worked from a signal box. The gates must not be capable of being opened at the same time for the road and the railway, and must be so hung as not to admit of being opened outwards towards the road. Stops to be provided to keep the gates in position across the road or railway. Wooden gates are considered preferable to iron gates, and single gates on each side to double gates. Red discs or targets must be fixed on the gates with lamps for night use, semaphore signals in one or both directions interlocked with the gates may be required; such signals will be necessary with double gates. At all level crossings of public roads or footpaths a footbridge or subway may be required. At occupation and field crossings the gates must be so hung as to open outwards from the line. Sidings connected with the main lines near a public road level crossing to be so placed that shunting may be carried on with as little interference as possible with the level crossings,

and as a rule the points of the sidings to be not less than 100 yards from the crossing.

At public road level crossings in or near populous places the lower portions of the gates to be either closed barred or covered with wire netting.

MODES OF WORKING SINGLE LINES.

1. Train Staff and Tickets combined with absolute block telegraph.

2. Train Staff only and one engine in steam or two or more engines coupled together.

3. Electric Train Tablet or Electric Train Staff system under which only one of the Tablets (or Staffs) applying to any section can be in use at the same time; the approval of the Board of Trade to be obtained for the apparatus proposed to be used, and for the rules of working.

Note.—Various forms of Electric Tokens are in use on the different railways: the latest type which has been adopted by the Great Western Railway is Tyer's Key Token instrument.

It may be taken that the introduction of such Electric Token Instrument in place of the staff and ticket system will, in addition to securing greater safety of working enormously increase the carrying capacity of a single line railway.

DESCRIPTION OF VARIOUS TYPES OF SIGNALS, AND PURPOSES FOR WHICH USED.

While the fixed signals of the various railways in this country have, owing to the requirements of the Board of Trade, been brought to some degree of uniformity, in matters of detail there is still considerable variation in practice. This is particularly so in regard to the forms and uses of subsidiary signals and in the materials and methods of construction of running signals. Most railways have a standard to which they rigidly conform, but differing in many respects from that of other companies, with the result that any generalization in regard to British Railway Signalling is open to many and varied exceptions.

SIGNAL POSTS.

Signal posts are in most cases made of pitch pine, mainly on account of its strength, durability and cheapness, and the fact that it is readily obtainable in suitable lengths of good size. They are generally about 7 in. square in section at the top, increasing by $\frac{1}{4}$ in. per foot to 12 in. or 14 in. at the bottom. The butt or portion below ground (which should be about 5 ft. for posts up to 20 ft. in height) is anchored by means of crosspieces and struts, and should be either charred and tarred or treated with creosote or other preservative. Above ground the posts are usually painted black for the first 3 or 4 ft. and white or stone colour for the remainder, and are surmounted by a cast-iron or zinc cap or ornamental pinnacle of wood. All signals over 30 ft. high should be stayed by seven guy wires of galvanized iron (No. 17 gauge) attached to eye bolts at the top of post and carried to cast-iron anchors well embedded in earth, or otherwise suitably secured. Iron or steel posts stepped into a cast-iron base are used on some railways, the London and South-Western Railway Company, for instance, having adopted as a standard a post of wrought-iron lattice pattern. Posts of reinforced concrete, which is claimed to be cheaper than wood, are also being experimented with on one leading railway. They are round and made in lengths of 30 ft. to 35 ft. with a diameter of from $6\frac{1}{2}$ in. to $9\frac{1}{2}$ in. at the top and 10 in. to 18 in. at the base. The posts are hollow and reinforced longitudinally and spirally, the strengths varying from 100 lbs. to 1,500 lbs. wire pull.

In the case of bracket signals, a stage of angle iron crossed by wooden treads, usually supported on wrought or cast-iron brackets, is necessary. The signal ladders are of iron with round $\frac{5}{8}$ in treads and are secured to the post with stays according to height. Separate ladders are required for the arms of bracket signals which cannot be reached from the stage.

A frequent method of carrying several signals across running lines is by means of a light bridge or gantry. These are, in many cases, constructed entirely of iron or of lattice steel work; in others the gantry and the dolls are of wood. The practice has much to recommend it where several sets of rails can be spanned, the driver obtaining a clearer view of his signals than is possible where the latter are placed at the side of the track.

SIGNAL ARMS.

The two-position lower quadrant semaphore arm is almost universal on British Railways. It is generally made of yellow pine, cedar or mahogany, and fixed on a spindle running through the post, but sometimes on a bearing at the side. The arm is actuated by rodding, with a counterbalance weight to ensure its return to the "danger position. Two types of arms are employed, *viz.*, the square-ended for stop signals and the swallow or fishtailed for distant signals. The arms of all running signals are carried on the left-hand side of the post and are painted red with a white band or spot on the side facing the trains they control, and white with a black band or spot on the reverse side.

The normal dimensions for a Distant or a Stop signal arm for a post up to 25 ft. in height are :—

48 in. long to post.
12 in. to 10 in. wide.
$\frac{7}{16}$ in. to 1 in. thick, tapering from post.

For posts over 25 ft. in height a 60 in. arm of the same width and thickness is usually provided. The arms are held horizontally to indicate the "danger" or "stop" position, and lowered to an angle varying from 45° to 60° to the post in order to represent "all right." On the Great Northern Railway the "all right" position is parallel to the post, the arm being pivoted in the centre and balanced without the aid of the spectacle, which is carried on a separate spindle. A thin steel arm is in general use on the London and North-Western Railway. This is 11½ in. wide at the tip, and $\frac{1}{8}$ in. thick, with two longitudinal corrugations in it each $\frac{1}{2}$ in. deep and 2 in. wide to act as stiffeners. These arms may be either vitreous enamelled or enamel painted, and can, therefore, be quite readily cleaned.

SPECTACLES.

The front spectacle is secured by bolts to the signal arm, to which it acts as a counterweight and ensures the arm going to danger in the event of the balance lever or the upright rod becoming broken. The red and green glass in the upper and lower portions respectively is usually puttied in and secured by split pins passed through the casting. In the case of the centre-balanced arm, the spectacle is not attached to the arm, but to a spur secured to

the spindle, which is actuated by the crank attached to the upright rodding. In cases where the Signalman cannot see the front of the signal, back spectacles or "blinkers" are required behind the lamp so arranged as to obscure the back lens when the signal arm is lowered.

SIGNAL LANTERNS.

Signal lanterns are constructed of tinplate, copper or cast iron, principally the former, and vary in size to suit the individual requirements of the various companies.

For gas-lit signals copper lanterns are most suitable and will last for about twelve years, which is also about the life of a tin lantern for an oil-burning signal. Cast-iron cases are practically indestructible, but are heavy and require stronger bracketing and staying.

A 6 in. bull's eye lens capable of adjustment is fixed in the front of the lantern of running signals, and a 1½ in. or 2 in. lens in the back. In the lanterns of subsidiary air signals, such as "Calling On," "Shunt" and "Backing" signals, smaller front lenses of 2½ in. or 3 in. diameter are used.

FIXED SIGNALS.

Fixed signals are divided into two main classes, *viz.*, "running" and "subsidiary." The former comprises Distant, Home and Starting signals, and the latter the less important signals used for slow speed movements, such as Siding, Shunting, Backing and "Calling-on," etc., signals.

DISTANT SIGNALS.

This is a "caution" signal, and may be passed at "Danger," but is perhaps the most important of the running signals in that when it is at "All right" it indicates that all the stop signals applying to the same line worked from the Signal Box immediately in advance are also at "All right." If, on the other hand, the arm is at "Danger," it is a warning to the Driver to be prepared to stop at the Home signal. For this purpose the Distant signal must be placed sufficiently far back, the distance varying with the gradient, curves, etc., from 600 to 1,060 yards or more.

If the signal boxes are too close together to permit of the Distant signal being placed out the prescribed distance from the Home signal, it has then to be placed underneath the Home, Starting or Advanced Starting signal of the box in the rear as a slotted or "controlled" signal.

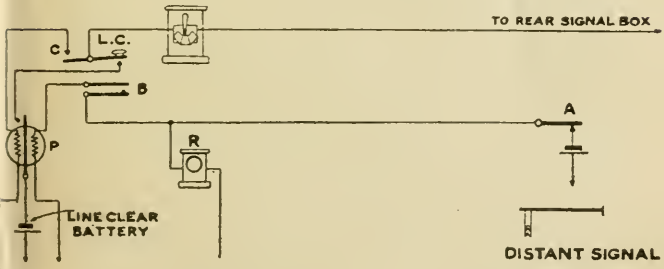
For splitting junctions over which trains may run at full speed in each direction, two Distant signals are required on brackets of equal height. In cases where the speed over one line at a splitting junction has to be considerably reduced, it is now the recognised practice to provide only one Distant arm, which is lowered for the high speed route alone.

Some Companies adopt the practice of fixing Distant signals permanently at " Danger " if there is a restriction of speed to 15 miles per hour or less at any point between the Distant signal and the most advanced Starting signal worked from the same box. In such cases the spectacle is removed from the arm and a red bull's-eye lens placed in the signal lantern, and the arm repeater, if provided, is removed.

An attempt to provide some distinctive indication of the Distant signal by night, apart from its isolated position or as a lower arm under a stop signal, has been made on some railways by means of a signal lamp possessing an outward extension with an inclined back painted white and a front of silvered glass. The side rays from the lamp are reflected by the back and front, and an angle being cut out of the latter causes an arrowhead of light to appear, indicating the character of the signal.

Where special attention has to be paid to the working of the Distant signal by reason of curves or excessive distance from the box, the block telegraph instrument has, on one leading railway, been interlocked with the Distant signal in such a manner that unless the arm is in the correct danger position, the Signalman is unable to peg " Line clear " for a train to approach.

The manner in which the working of the Distant signal is interlinked with the block telegraph indicator circuit is shown in the accompanying diagram.



" A " represents the contact made when the Distant signal is " on " and " R " is the electric repeater. " L.C." is the " Line Clear " key of the block telegraph indicator to the rear Signal Box—(the " Train on Line " key is omitted for simplification). When the " Line clear " key is pegged down it closes a contact (B), which puts in parallel with the electric repeater one winding of a polarized relay (P), and if the distant signal is " on," current flows from the battery at the distant signal through this winding of the polarized relay, causing the armature of the relay

to be deflected to the left. This causes the " Line Clear " battery to be connected to the front of the " Line Clear " key. Unless, therefore, the distant signal is " on " the " Line Clear " signal cannot be sent.

When the Distant signal is lowered current through the polarized relay is reversed, and unless other provision were made, the " Line Clear " indication would be interfered with, through the armature of the polarized relay being deflected from its left-hand contact. To prevent this there is another winding on the polarized relay which, when the " Line Clear " key is pegged down, is connected by the closing of the contact " C " parallel with the block instrument line, so that current can pass from the " Line Clear " battery through the second winding of the polarized relay. This current is stronger than the current from the distant signal battery, and therefore capable of continuing to hold the armature of the polarized relay to the left after the distant signal has been lowered.

HOME SIGNALS.

Home signals are placed immediately to the rear of signal boxes, crossover roads, siding connections or junctions. At facing junctions they are fixed on brackets with the arm for the more important line at a higher elevation. At many busy junctions Home signals situated a quarter of a mile to the rear of the ordinary or Inner Home signals are provided. These allow of trains being accepted with freedom from each direction towards the junction under normal block working conditions. Delays are thus avoided, but in order to remind the signalman of the presence of the train at the Outer Home signal, a short length of track circuit in combination with a visual indicator in the box should be provided. It is usual also for the occupation of the track to lock the stop signal immediately in rear of the track circuited signal and to either hold the block indicator at " Train on line " or prevent it being put to " Line Clear."

STARTING SIGNALS.

Starting signals control the entrance of trains into the block section in advance. They are located at the end of the station platform or a full train's length ahead of trailing points. At places where there is a crossover road or a siding connection beyond the starting signal, an Advanced Starting signal is required. There should, if possible, be an uninterrupted view from the signal box of trains or engines standing at Starting or Advanced Starting signals, and when this cannot be obtained, some form of electrical reminder should be given the signalman, such as track circuit or a reply push bell on the signal post, the former being preferable.

ELECTRICALLY-WORKED "BANNER" SIGNALS.

These consist of a circular iron frame with glass front and opal glass back, between which is a red arm pivoted in the centre. They are frequently used as Platform Starting signals, particularly at large termini, or in positions at stations where there is a difficulty in fixing ordinary semaphore signals. The frame is usually 2 ft. 6 in. in diameter, but where used as a "Calling-on" or other subsidiary signal, is reduced in size to 1 foot.

ELECTRICAL REPEATERS.

These are provided where the signals are not within the signalman's vision in order to inform him of the position of the arms. They consist of an indicator in the signal box actuated by mercurial or electrical contact. When the signal is at danger the repeater shows "Signal on," and when the arm is fully lowered "Signal off." Directly the arm is deflected from the horizontal position and until it is properly lowered the repeater shows "Wrong." In other cases a miniature signal in glass frame is provided, which repeats the actual movements of the signal arm.

A "light" repeater is also frequently provided in combination with the last-named apparatus, in order that the signalman may be aware if the signal lamp is not burning properly. As long as the light gives sufficient heat, an expansion bar within the signal lamp maintains an electrical contact and indicates "Lamp in" on the repeater. Should the light fail, however, and the temperature in the lamp be lowered, the bar contracts and breaks the contact, with the result that the repeater at once shows "Lamp out," and, if necessary, the simultaneous ringing of a bell calls the attention of the signalman to the fact that the light is not burning. Fig. 1 illustrates Tyer's Simple Electric Signal and Light Repeater. Fig. 2 shows Tyer's Patent Light Expander. Fig. 3 shows same attached to Lamp. Fig. 4 shows a G.W. Lamp Indicator.

ARM AND LIGHT REPEATER.

The repeater (Figs. 3 and 4) is arranged to repeat either the arm or the arm and the light combined by means of switch 1, which, when it is pointing to "ARM and LIGHT" as shown with the outside semaphore arm in the off position, joins contacts 2 and 3, which allows a current to pass from battery 4, through contacts 5 and 6 on commutator, wire 7 to thermostatic expander contacts 8 and 9, line wire 10 to switch contacts 2 and 3, wire 11 and coils 12 and 13, which operate arm 14 to "OFF" position and thence return by means of earth or return wire to battery 4. Contacts 15 and 16, also joined when switch 1 is in this position, complete a local circuit from battery 17 through wire 18 to contacts 19 and 20, wire 21 to lamp 22 and back through wire 23 to battery 17. The light from lamp 22 shines

through the green spectacle 25 when the arm 14 is in the "OFF" position. The contacts 19 and 20 are joined when the arm 14 is in either the "ON" or "OFF" position by cam 24, which is fitted on spindle of arm 14.

With the switch still pointing to "ARM and LIGHT" and the outside semaphore arm is at danger a current of reverse polarity passes from battery 30 through contacts 31 and 6 on commutator, wire 7 to thermostatic expander contacts 8 and 9, line wire 10 to switch contacts 2 and 3, wire 11 and coils 12 and 13, which now operate arm 14 to "ON" position, and thence return by means of earth or return wire to battery 30. The light from lamp 22 now shines through the red spectacle 26.

During the day when the arm need only be repeated the switch is pointed to "ARM." Then with the outside semaphore arm in "OFF" position the current from battery 4 passes through contacts 5 and 6, line wire 27 to switch contacts 28 and 29, wire 11 to coils 12 and 13, which operate arm 14 to "OFF" position and thence return by means of earth or return wire to battery 4.

With the switch still pointing to "ARM" and the semaphore arm at danger, a current of reverse polarity passes from battery 30 through contacts 31 and 6, line wire 27 to switch contacts 28 and 29, wire 11 to coils 12 and 13, which now operate arm 14 to "ON" position and thence return by means of earth or return wire to battery 30.

When the switch points to "ARM and LIGHT" with the semaphore arm in neither the "DANGER" nor the "OFF" position, or should the lamp be out or burning dimly, the arm 14 will go to "OUT OF ORDER" position, which is indicated by an arrow midway between the "ON" and "OFF" position, and lamp 22 will not light. The switch when midway puts the repeater to the "OUT OF ORDER" position.

The semaphore arm is shown in the "OFF" position, this indicating more clearly the operation of the switch contacts.

Where electric lamps are used for lighting in connection with semaphore arms the thermostatic expander contacts can be replaced by a relay in circuit with the electric lamp, the relay contacts being substituted for the expander contacts. Should the electric semaphore lamp fail the circuit is broken through the relay, and the repeating lamp in the cabin is automatically extinguished.

The case can be either of wood or metal, and can be adapted for Upper Quadrant or 3-position working as desired.

Very small battery power is required, and the maintenance is very slight. The repeating lamp will last a considerable period, as only half normal current is used for same.

Fig. 1.

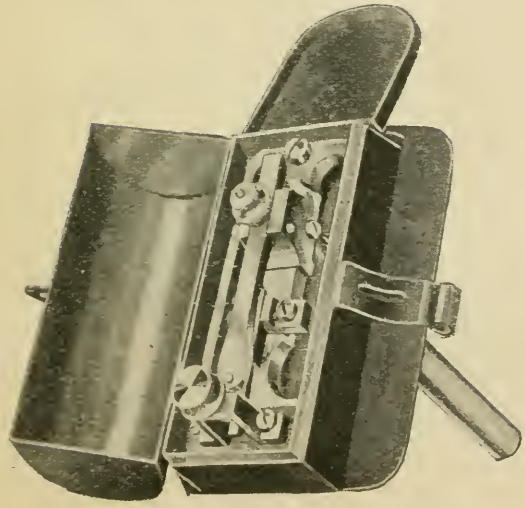


Fig. 2.

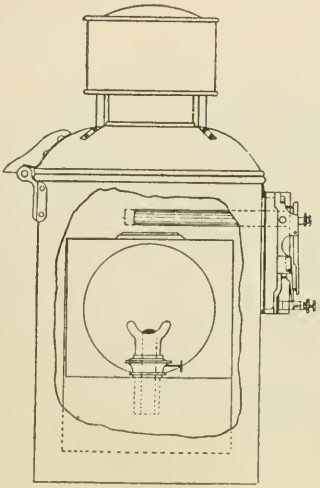


Fig. 3.

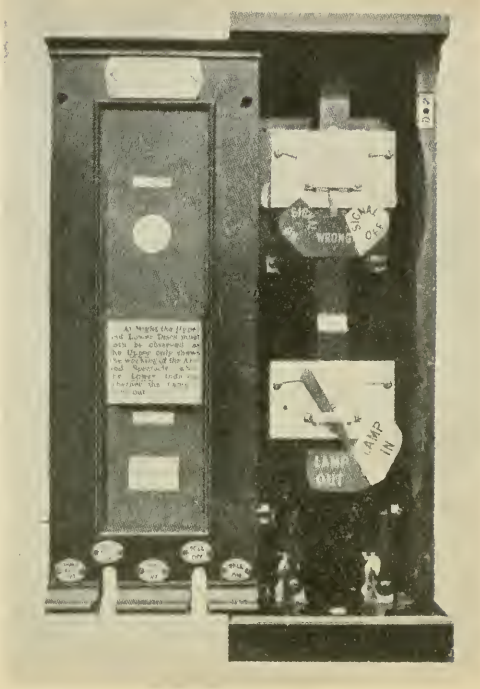


Fig. 4.

Fig. 4.

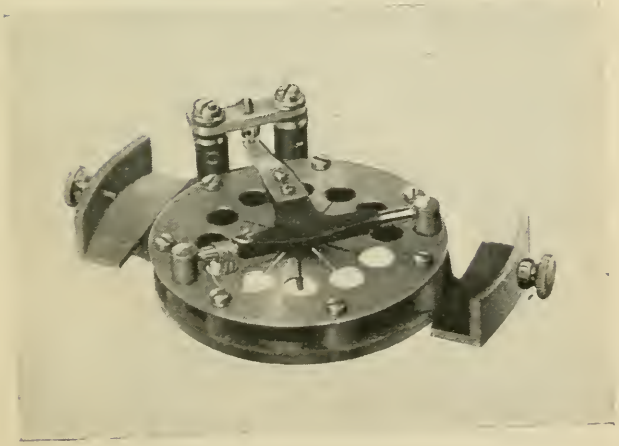
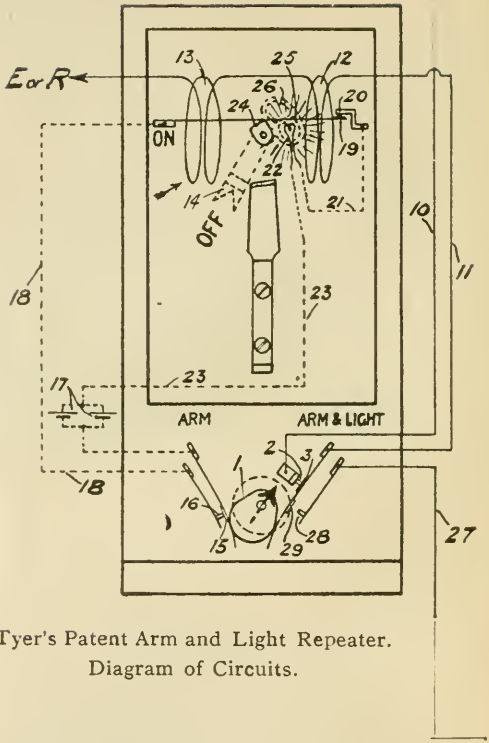


Fig. 5.



Tyer's Patent Arm and Light Repeater.
Diagram of Circuits.

CIRCULAR THERMOSTATIC EXPANDER.

Fig. 5 shows Tyer's new form of Thermostatic Expander of a circular type, for operating the electrical repeater in the signal box, to denote whether the lamp is alight or otherwise. It is not affected by atmospheric conditions, direct rays of sunlight, etc., only being operative when subjected to a direct flame applied towards the centre pivot.

The expander is of simple construction, consisting of

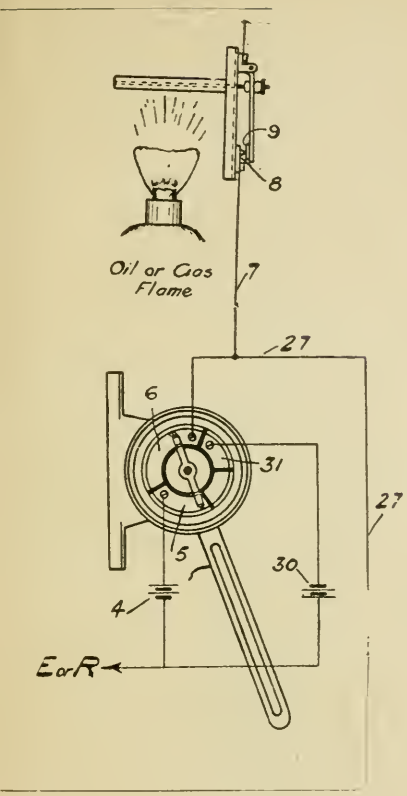


Fig. 5.

a circular skeleton plate, slightly convex, the expansion of which causes electrical contacts making and breaking as the case may be. The design is such that it can be readily adapted to almost any type of lamp, and can be fitted inside the cover so that everything is protected, excepting the contacts, which are covered by a small cap.

This Expander is meeting with great success and bids to become the adopted standard.

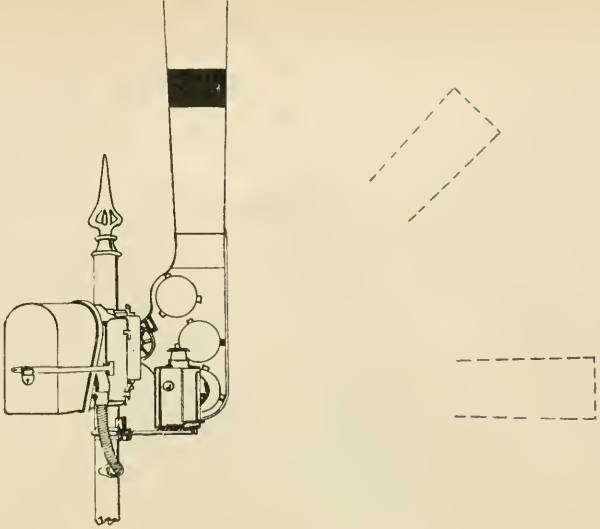
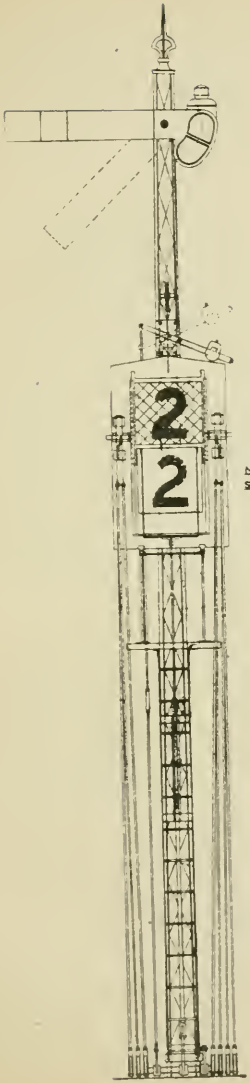


Fig. 5

UPPER QUADRANT THREE-POSITION SIGNAL
(ALL ELECTRIC)



Route
Indicating Signal.

This form of repeater, especially in view of the extensive use of long burning signal lamps, should prove a great boon to signalmen to assure them of the efficiency of the lamp flame, as half flame or under will cut out the light circuit in the Repeater, causing the arm to go to the neutral position and the light to be extinguished.

ROUTE INDICATING SIGNALS.

In place of the multi-armed signals hitherto in use at many large stations and yards, a new type of single arm signal with route indications is being largely adopted. A usual form is the provision of a rectangular opal screen below the signal arm, which shows a white ground by day and also at night, when it is illuminated by a lamp with a specially constructed lens and reflector at the back. The figures are cut out on slides of sheet zinc, like stencils. When the signal is normally at "Danger," the slides are out of sight in the slide box above or below, the screen, but they are placed in front of the screen when the levers operating them are pulled over in the Signal Box, and the figures by day appear white on a black ground or *vice versa*. Among the many advantages of the system is the question of simplification, only one arm or light having to be looked for, instead of picking out a certain signal from a complicated group. A clear and unmistakable indication is also given to the Driver of his destination, while the economies in reduction of first cost and subsequent upkeep of a lessened number of arms and lamps are considerable (p. 29).

"THREE-POSITION" SIGNALS.

The experimental introduction of "three-position" (upper quadrant) signals has recently taken place on the Great Western Railway. This type of signal (p. 28) gives three indications, the arm being raised from the horizontal or "Danger" position to the vertical or "All right" position The intermediate position at 45° for "Caution" carries an orange light and indicates that the section ahead is clear to the next stop signal only, thus taking the place of the verbal "warning" arrangement.

ELECTRICALLY WORKED SIGNALS.

With the view of overcoming difficulties attendant on working signals mechanically when at a considerable distance from the levers controlling them, electric motors are obtainable which can be affixed to any type of signal post and will work any semaphore arm with standard fittings. With the Siemens type of motor a small primary battery only is necessary to lower the semaphore arm to the "clear" position, the amount of electrical energy expended being extremely small. This type of motor is

peculiarly adaptable where slotting is necessary, as in the case of a lower distant arm or where signal wires passing unprotected through tunnels are apt to become defective, and also for operating signals automatically by track circuit or other device. The cast-iron case in which the motor is enclosed can be attached to either the top or bottom of the signal post, the advantage of the topmast position being that the arm is directly operated by the train of gears. (For Tyer's Signal Motor, see p. 97).

DUPLICATE ARMS.

High signals, the driver's view of which is temporarily obstructed by an overbridge, or other obstacle, are provided with duplicate or co-acting arms of the same pattern as the upper arms, slightly reduced in length and fixed lower down the post. These are also found of great service in time of fog.

HOISTING GEAR.

Where signals are over 30 ft. in height, hoisting gear is now frequently provided. This resembles that on a street arc light standard and enables the lamp to be raised and lowered, thus avoiding the necessity of the lamp-man having to climb the ladder for the purpose.

SUBSIDIARY SIGNALS.

Other fixed signals which are commonly used in conjunction with the main running signals already described are :—

CALLING-ON ARMS.

These are fixed upon the Home signal post beneath the Home signal, and consist of a short arm which, as its name implies, is used to indicate to the driver that he may draw forward with caution as far as it is clear when the line ahead is occupied. They are often provided when the Home signal is not near enough to the signal box to enable a signalman to communicate verbally with a driver after stopping him at the Home signal. Calling-on arms on some lines show no light when at "Danger" at night. They are of various shapes and designs, being purposely made as insignificant as possible and range from simple small arms to scissors and hammer-head signals.

SIDING SIGNALS.

Control the exit of trains from sidings They are usually low semaphores with short arms. On the Great Western Railway they are distinguished by a ring on the arm. When two or more directions require to be indicated the latest practice is to provide "route-indicating" signals.

BACKING SIGNALS.

In cases where it is necessary to "back" frequently over points, or for a short distance along a running line for the purpose of reaching another line, Platform or Siding, low "backing" or "wrong line" signals are often provided. These are on some lines distinguished by having two holes in the arm, and show a small white light in the normal position and a small green one when at "All right."

"SHUNT" SIGNALS.

"Shunt" signals, used on some railways, are always fixed as a small lower arm on the most advanced signal controlling entrance to the section ahead, when it is necessary for a train or engine to frequently draw past the signal for shunting purposes only. The difficulties and risk of misunderstanding in giving verbal instructions from the signal box are thereby obviated. These signals are sometimes distinguished by a large "S" on the arm.

GROUND DISC OR DWARF SIGNALS.

Govern movements over trailing points. Ground discs are of two kinds, the point disc and the independent disc, the former working with the points and the latter operated by independent lever. The independent pattern of disc is usually fitted with a miniature signal arm. The lights of all disc and dwarf signals are small, the lenses being 1½ in. or 2 in. in diameter. The last issued Board of Trade regulations provide for the use of white instead of red lights in discs or dwarf signals, except when the signals control movements from sidings to main line or in and out of running loops.

FOG SIGNALLING.

Mechanical aids to the placing of detonators with a view to economy of men and material are in use to a considerable extent. These are either worked by the fogman himself or are actuated direct from the Signal Box.

DETONATOR LAYING MACHINES (Fig. 6)

Enable a fogman to fog for the signals applying to two or more lines without crossing intervening rails. One form of apparatus known as the "Pinder" is used largely on the Lancashire & Yorkshire and Great Western Railways and consists of a winding wheel with an endless chain in wooden troughing running under the intermediate line or lines and curved slides along which the detonator carriages work to and from the rail. When a detonator is exploded the fogman draws back the carrier and recharges it, but if the signal is lowered, he turns the wheel sufficiently to remove the detonator clear of the rail. An indicator

showing when the detonators are on or off the rail is provided at the fogman's end. Another form is the Clayton Fog Signalling machine, which is provided with a magazine at the side of the rail containing a supply of detonators in tin clips. A pair of jaws worked by a lever from the box gives the detonators one by one and places them on the rail or removes them as required.

DETONATOR ECONOMIZERS (Fig. 7).

These machines, which may be used separately or in connection with the detonator-laying machine described above, are designed to avoid the loss involved in the system of using two detonators to ensure one report by utilizing the force of the explosion of the first detonator to withdraw the second one from the rail before the wheel reaches it, while retaining the advantage of keeping a second detonator on the rail to provide against failure or skidding. The apparatus consists of a bar threaded through two eyes on the sleepers and provided with stop and flynut in order to prevent it approaching too near the rail. At one end is a plate fixed at right angles to the rail, and at the other end farthest away from on-coming trains a crank to which a tin holder with a detonator clipped in is swivelled by means of a pin. When the first detonator, which is placed on the rail two inches to the rear of the plate, explodes, it throws back the plate, revolves the crank, and removes the second detonator before the wheels of the engine reach it. Should the first detonator fail or be skidded, the second will explode, and a new tin holder and detonator has then to be provided.

DETONATOR PLACER MACHINES (Fig. 8).

These are made in various designs and are either worked automatically off the signal wire or by a lever from the signal box. Their function is to place two detonators on the rail in advance of the Home signal when that signal is at " Danger." When not on the rail head the detonators are under cover in an iron casting fixed close to the rail and slightly below rail level.

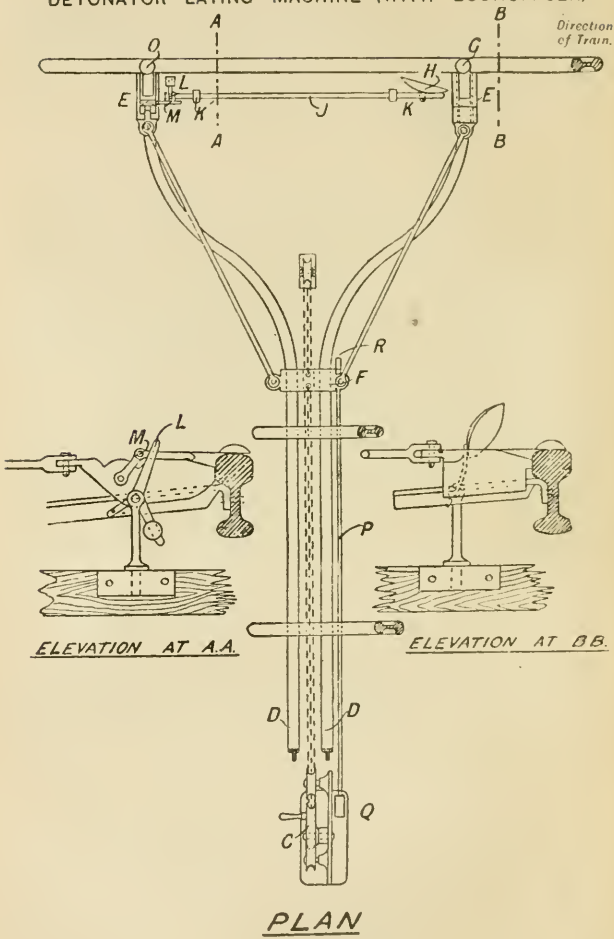

DETONATOR LAYING MACHINE (WITH ECONOMISER).
Direction of Train.
A
B
O
G
H
L
E
M
K
J
R
F
P
D
Q
C
ELEVATION AT A.A.
ELEVATION AT B.B.
PLAN

Fig. 6.

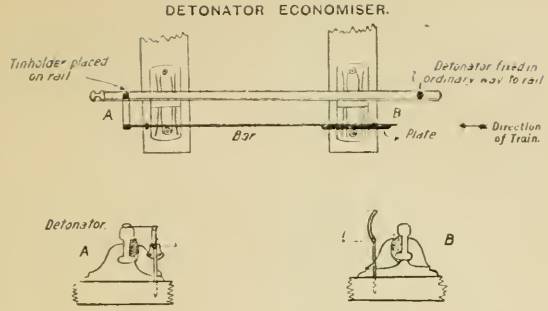

DETONATOR ECONOMISER.
Tinholder placed on rail
Detonator fixed in ordinary way to rail
A
B
Bar
Plate
Direction of Train.
Detonator.
A
B

Fig. 7.

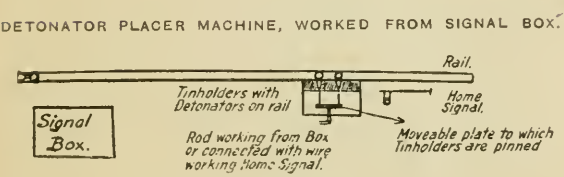

DETONATOR PLACER MACHINE, WORKED FROM SIGNAL BOX.
Rail.
Tinholders with Detonators on rail
Home Signal.
Signal Box.
Rod working from Box or connected with wire working Home Signal.
Moveable plate to which Tinholders are pinned

Fig. 8.

SIGNAL BOXES.

There are many varieties of Signal Boxes, the type and size being governed by local circumstances, and from the outset it has been the practice to enclose the levers operating signals, points and lock bars in a cover or building, the position chosen being such that the signalman can see as much as possible of the yard he controls ; yard being defined as the area of railway between the Signals in each direction.

As far as is practicable the signal box should be built as centrally as convenient with regard to the layout under control. In some cases, owing to the exigencies of space, the box would have to be carried on a bridge or supports over the railway. According to standard British practice Signal Boxes should not be built more than 200 yards from the facing points in either direction ; in special circumstances this may be extended to the maximum of 250 yards, and in the case of training points 300 yards is the greatest distance.

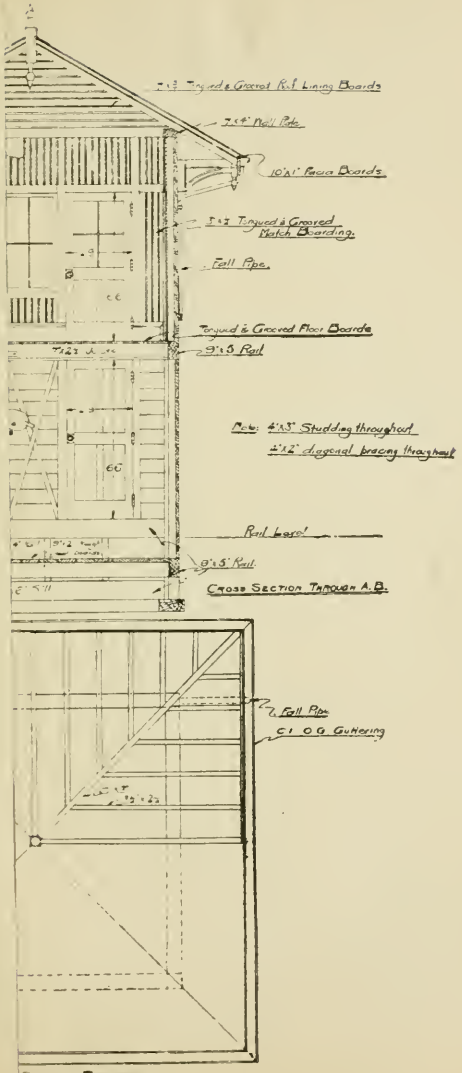
Signal Boxes may be constructed either wholly of brick, stone or timber, or the under portion brick with timber framing above. If the ground is newly made a timber box is most desirable, being of lighter construction than brick or stone. Where the sunshine is excessive the roof should overhang to afford protection from the direct rays. In country districts oil is the artificial illuminant, and where available near and in towns gas and electric light are used. Water or earth closets should be built within easy reach and, if possible, a W.C. should be embodied in the building itself. A coal and ashbin is also required. A desk is necessary for the booking of trains, and a clock must be provided, also a small cooking stove. Cupboards and lockers in which to keep overcoats, detonators, hand lamps, flags, etc., are also necessary.

An oil hut is a desirable adjunct if there is not a lamp-room available at the station, as it is not a good practice to use the under part of the signal cabin for lamp cleaning and oil storage.

Locking frames have to be periodically inspected and oiled, and where high frames are in existence a second floor has to be provided underneath the box to facilitate maintenance and a signal box should always be designed to suit the locking gear. On the top floor ample space should be allowed for the instrument shelves for block apparatus, repeaters (which should be fixed close to the levers working them), train describers, track indicators, telephones and single-needle instruments, and where the line is single the tablet instruments should be fixed on tables at either end of the cabin nearest to which station they apply.

The height of box from rail to floor level should be such as to admit of the signal man having a good view of the tail lamps of all trains.

Figure 9 illustrates a good example of a wooden signal Cabin showing the Interlocking Apparatus fixed in position.


1"x3" Tongued & Grooved Roof Lining Boards
3"x4" Wall Plate
10"x1" Fascia Boards
5"x2" Tongued & Grooved Match Boarding
Fall Pipe
Tongued & Grooved Floor Boards
9"x3 Rail
Note: 4"x3" Studding throughout
2"x2" diagonal bracing throughout
Rail Joist
9"x3" Rail
CROSS SECTION THROUGH A.B.
Fall Pipe
C.I. O.G. Guttering
ENLARGED TRIMMING

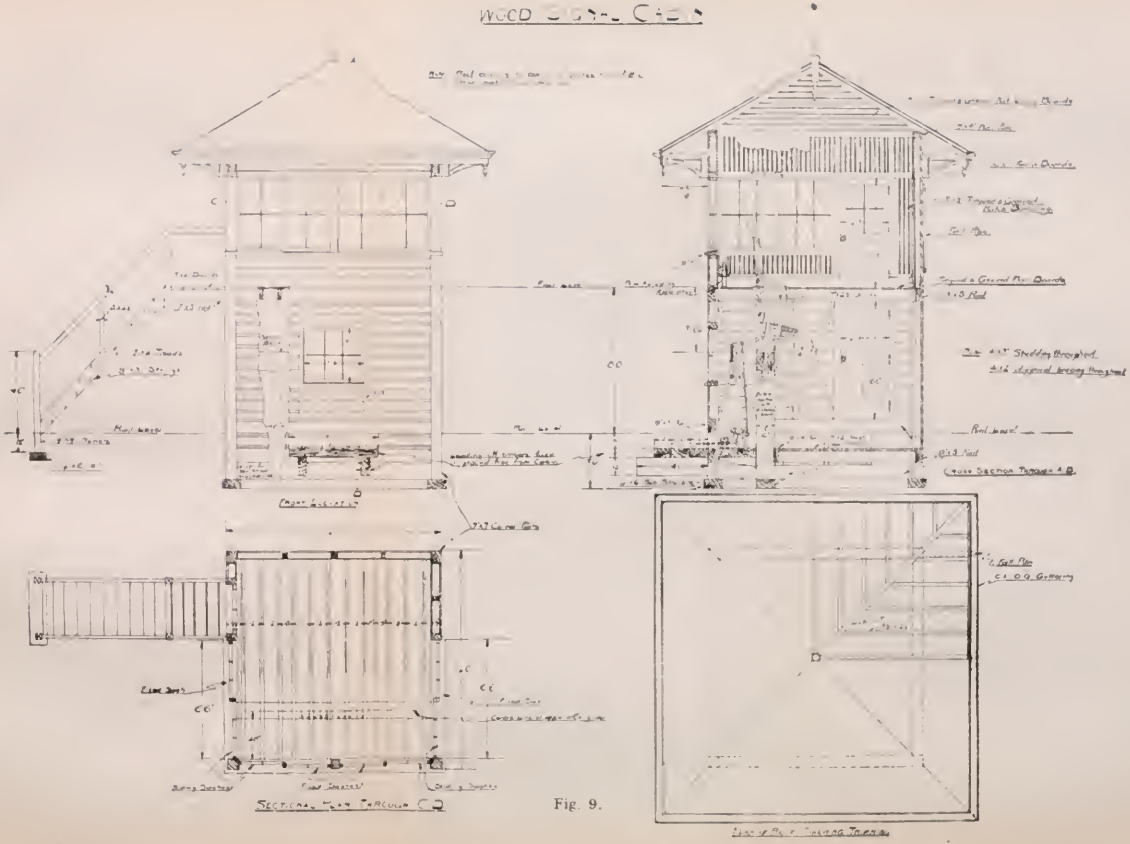


Fig. 9.

Facing page 36

SIGNAL LIGHTING.

Considerable progress has been made in connection with signal lighting since rape oil was abandoned in favour of petroleum, and with the advent of reliable "long burning" lamps the high-water mark of economy with efficiency seems to have been attained. The type of long-burning lamp most extensively used on British Railways is that made by the Lamp Manufacturing Company (Fig. 1), which will burn for about eight days without attention and is fitted with an auxiliary wick which does not come into contact with the flame at all, but the upper part of which is coiled round the main wick tube, the latter being perforated with holes about ⅛ inch diameter. Burning night and day, this lamp consumes about seven gallons of petroleum per annum. The principal advantages of long-burning lamps are their extremely low maintenance cost and avoidance of wastage of oil which daily filling of the lamps involves; the fact that they are always alight in the event of fog, or snowstorms coming on; that the signals at switched-out boxes are always in evidence to enginemen, and that risk of accident to lampmen is greatly reduced in consequence of the signals only having to be visited and the ladders climbed once a week instead of daily.

Fig. 2 shows the Adlake long-burning lamp, which is also in great demand. Fig. 3 is a type of long-burning lamp brought out by Messrs. Linley & Co. Fig. 4 shows Messrs. Tyer & Co.'s lamp; a very good type of lamp, and very largely used on the Colonial Railways.

Instead of the signal lamps being attended to by the station staffs, it is the best arrangement under this system for a lampman to be placed in charge of a district embracing (according to the extent of the ground to be covered) from 200 to 300 lamps. A small corrugated iron or brick lamp-room about 6 ft. by 6 ft. should be provided at each station, or at convenient points in large yards, for lamp cleaning and oil storage purposes.

Lamp sticks ("carriers") should be supplied to the District Lampmen, on which they can carry four lamps, in order to reduce walking as far as possible. A programme should be drawn up showing exactly the lamps to be dealt with each day, and the stations in the district supplied with copies. Spare lamps in the proportion of 10 per cent. should be kept on hand in the lamp rooms, and cleaned, filled and worked round in turn with the other lamps to obviate difficulty when lamp repairs become necessary. One trimmed signal lamp of each kind in use should always be kept in the Station Master's office or signal box in order that another lamp may be instantly available in the event of a signal lamp failing. Any case of failure should be specially investigated, as this tends to keep the District Lampmen up to their work—some

Companies supply Station Masters and signalmen with special forms for this purpose, although in actual practice failures very rarely occur.

As low-grade petroleum will not answer in long-burning lamps, the high-grade oil sold for the purpose must be used. The " White May " brand of the British Petroleum Company and the Anglo-American Oil Company's " long-burning " oil may be mentioned as being extensively used.

In order to ensure satisfactory results, the petroleum should be supplied in steel casks, as loss by evaporation is avoided ; the casks should also be well cleaned out every time they are returned to the depôt for re-filling purposes, so that there is no interior coating of glue or size to prejudice the burning qualities of the oil. The oil should be drawn direct from the casks into the lamps through a tap provided with a copper gauze strainer. Once a month the lamps should be completely emptied of the residue of oil left in them in order to prevent any accumulation of dirt or water. The greatest possible cleanliness should be observed in connection with the lamps, and the District Lampmen should be provided with the necessary materials for ensuring this, *viz.*, probes for cleaning burners, methylated spirit for removing discoloration on internal surfaces of lamps, and metal polish for brightening reflectors.

Good results are obtained by specially treating the wicks, *i.e.*, drying them thoroughly in a slow oven, plunging them for twenty-four hours in petroleum and afterwards packing them in air-tight canisters in 25's or 50's for despatch to the District Lampmen. These men should also be supplied with small pocket tins in which they can carry a few treated lamp wicks when on their rounds. The total cost of signal lighting by long-burning lamps, including oil, wicks and lampman's wages, should not exceed 10s. per lamp per annum.

Considerable economies can be effected by substituting long-burning lamps in gas-lit signals. Gas lighting is very expensive, not solely on account of the cost of the gas actually consumed, but owing to the perennial expense involved in maintaining the necessary gas piping and the loss of gas through leakage as the pipes become defective.

Electric lighting for signals is practically only followed at special places for particular reasons. It cannot, of course, compare with petroleum lighting from an economical point of view, but it has the advantage that the lights may be switched on or off in groups from the signal box.

A new acetylene gas " flashlight " system is adopted in Sweden, and in various other countries. By means of a special cylinder containing two months' supply or more of acetylene gas, which is fixed in a box at the foot of the signal post, and by a flashing mechanism in the lamp itself, a constant succession of bright flashes is produced of any required periodicity. The manufacturers of this lamp, which is known as the " Aga " flashlight

lamp, claim that a flashlight appeals more to drivers than does a continuous light. The Furness Railway Company have a number of these lamps already installed on their main line.

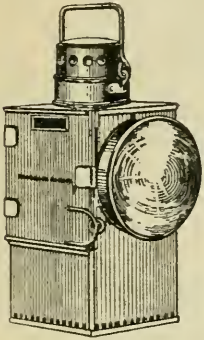


Fig. 1.

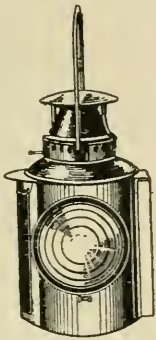


Fig. 2.

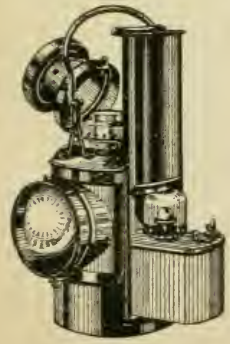


Fig. 3.

Fig. 4.

"SIGNALITE" LONG BURNING LAMP.

Tyer's "New Signalite" Lamp has been specially designed to provide a long-felt want for an improved signal lamp, and when used in combination with the Patent Adjustable Bracket the lamp may easily be adjusted to the desired angle required on curves.

In the case of lamps where the lens is adjustable there is always the possibility that when the lamp is replaced on the signal post after cleaning the adjustment of the lens is not correct.

It will be noticed from the illustration that the lamp is fitted with a thermostatic expander to enable the light to be electrically repeated in the signal cabin, where a signal is out of view of the signalman.

This expander is fitted at the back of the lamp in place of the back light and back spectacle since, for such signals, these latter two items are unnecessary.

The Lamp Container holds 1¾ pints of Oil and will burn continuously for over 200 hours.

The lamp is constructed with an inner and an outer door, may be inspected and regulated in its operative position on the signal post, in a gale or rain storm. This is made possible, as the inner door, which keeps out the draught, has an aperture through which the flame is inspected and regulated by the wick winder which projects through the door.

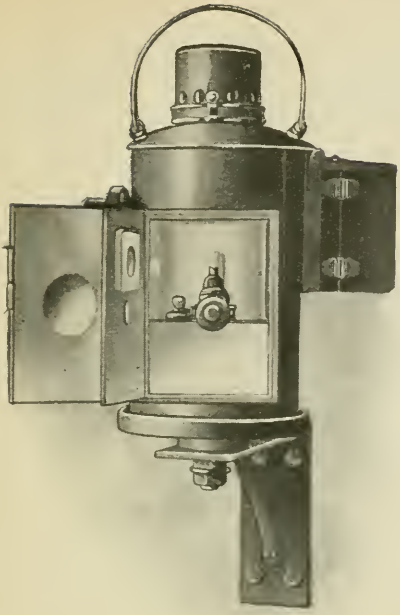
"JUSTABLE" BRACKET.

The bracket has the spigot attached to a plate which can be rotated to the right or left and can be adjusted without risk to the fitter.

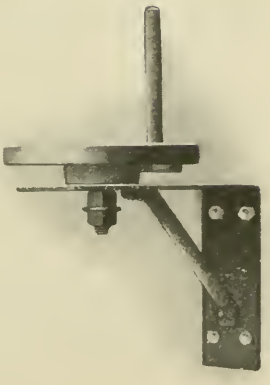
To set the lamp for a curve, place it on the spigot on the plate, loosen the lock-nuts underneath, rotate the plate until the lamp points in the desired direction. Tighten the nuts and the bracket is set.

By this system any of these lamps can be used indiscriminately for curves or straight roads, thus doing away with the use of slides on lamps, the bracket doing the work of the slides.

The use of these adjustable brackets admits of the "Signalite" Lamps being perfectly interchangeable.



"Signalite"
Long Burning
Oil Lamp.



"Justable" Bracket
for "Signalite" and
other Lamps

SIGNALLING SYSTEMS.

Signalling systems can be divided into three groups, *viz.*, manually operated, power operated, and those with power-operated signals and manually-operated points.

MANUAL SYSTEMS.

The essential feature of all these is the movement of points and signals by the Signalman pulling or pushing a lever or levers.

There are many systems available differing greatly in detail, but all endeavouring to obtain low first cost, reliability, easy operation and cheap maintenance.

The principal railways have their own systems and construct and maintain their own apparatus.

Some of the principal firms manufacturing signalling plant are :—

Tyer & Co., Ltd.
Stevens & Sons, Ltd.
Westinghouse Brake & Saxby Signal Co., Ltd.

The separate points of a signalling system will be considered in detail.

RODS AND WIRES.

To connect the lever to points, round solid rod, tube narrow channel and "T" iron are employed. This is known as rodding. Where the rodding has to leave the Signal Box, a bell crank is provided. To operate signals stranded steel or iron wire is employed. At corners grooved pulley wheels are fixed, and a chain or flexible steel cable is joined into the wire and passes over the wheel. Coil springs are now often inserted at the signal and in the box to take any jar.

The rods, which are usually in 16-ft. lengths, are joined together by bolts or screwed unions. In one system the ends are flattened out in a drop stamp, and bosses and recesses are left which fit together. Bolts pass through them to keep them in place, but do not take the pull.

Mild steel pins are used in holes in levers, etc., and the rods end in a fork with eyes.

Rodding is carried on rolling wheels, or journals mounted in guides every 6 ft.

It is essential that rodding should be lined up so as to work with the minimum of effort.

Allowance for alteration in length due to variation in temperature must also be made. This is done by means of compensators. Steel wire stretches with use, as well as altering with changes in temperature, and adjusters and tighteners are provided in the Signal Boxes.

POINTS.

These are connected together by stretcher bars, and the rodding is attached to it between the blades. This bar not only acts as a means of moving the points, but is responsible for keeping them to gauge.

Facing points (Fig. 1) are checked by locking bars, which prevent the points being moved while a vehicle of any kind is close to or on them.

A locking bar is carried on brackets attached to the under-side of the rail. Rocking links, one end hinged to the brackets and the other to the bar, allow the required motion.

The stretcher blade has two holes in it. A plunger, made to fit these holes closely, is operated from the Signal Box, in conjunction with the locking bar, and the home signal.

The operation of the points is as follows:—All signals are at "Danger." The locking bar is is pulled over, thereby ascertaining that the points are not occupied. The plunger is also withdrawn by the same lever. The points are now moved over by another lever. They must go right over to their correct position, otherwise the plunger cannot be inserted in the hole in the stretcher blade and the plunger or locking lever could not be pushed back completely in consequence.

Until this lever is pushed right back, no signals can be pulled off, owing to the interlocking not being free.

In addition to the above check on the movement of

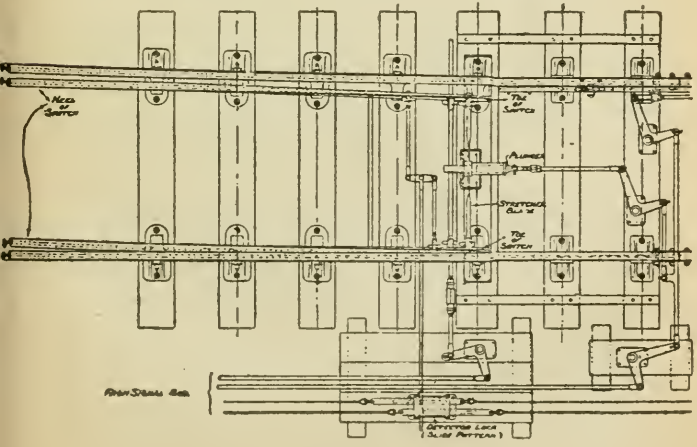


Fig. 1.

facing points, facing point detectors are attached separately to the poins.

These are of various types, a good example being shown in Fig. 2.

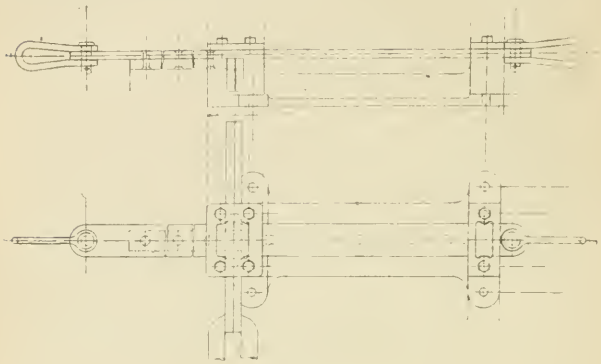
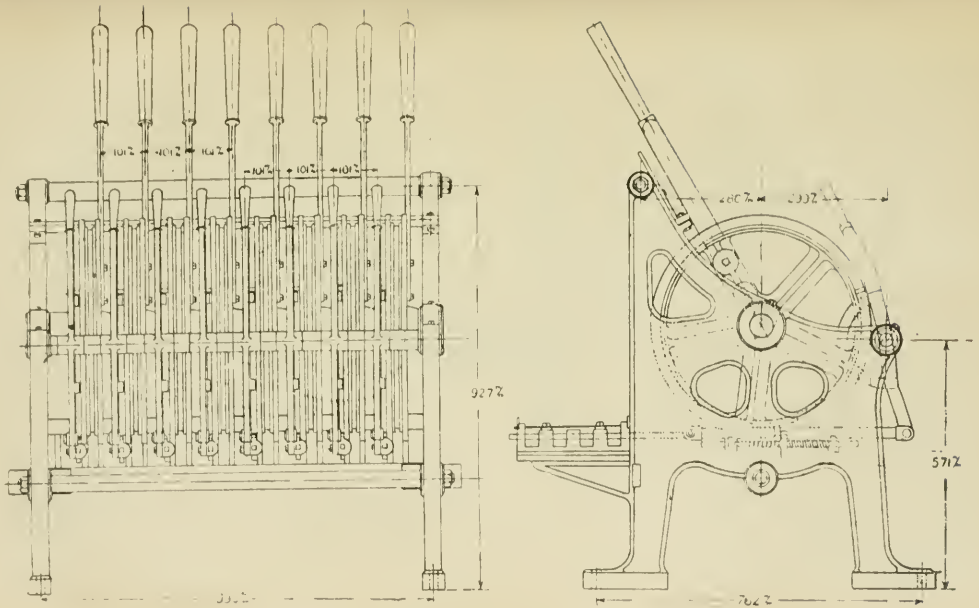


Fig. 2

Points can also be operated by the medium of wire. A good scheme of wire-worked points patented by Messrs Tyer & Co., Ltd., is such that the arrangement may be either trailable or non-trailable. This means that in the former case the points may be run through in a trailing direction, and the points not broken in any way due to the introduction of a trailable apparatus between the operating lever and the points. In the other scheme—non-trailable—the points do not admit of being burst through in a trailing direction, as no trailable apparatus is fixed in the run between the points and operating lever.

The diagrammatic illustrations (Figs. 1 and 2) show quite clearly the outline of both schemes, and are self-explanatory.

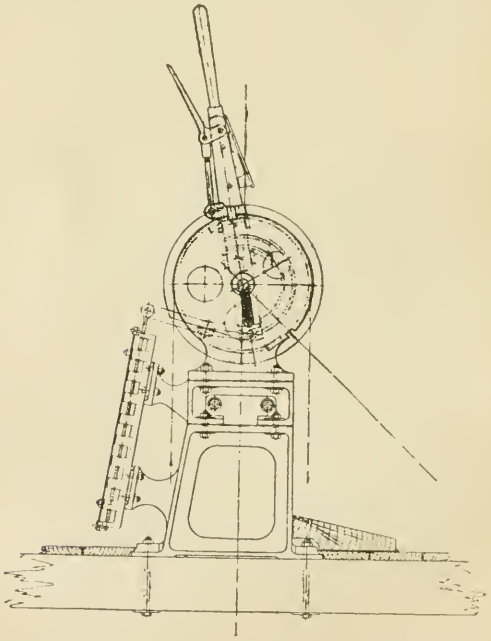
With regard to the trailable scheme, the operating lever, when pulled over, imparts the necessary motion through the trailable apparatus, and operates the scale-beam crank, which pulls the wire, and rotates the point movement box, the result being that the points are reversed. Suitable connecting pieces connect the wire, which should be solid galvanized steel wire—say, No. 6 gauge. Of course, as wire can only be pulled, a return wire has to be used. The special trailable apparatus makes it possible, as stated above, that the points may be run through in the trailing direction without any of the connections being damaged. The mechanism of the trailable apparatus is such that by the springing arrangement in same it can be



Interlocking Apparatus for Wire Worked Points.

re-set by a re-setting bar ; thereby rendering the whole of the apparatus normal for the next time the operating lever is pulled. It is interesting to note that the trailable apparatus enables the necessary adjustment to be made irrespective of the position of the lever in the frame.

With the non-trailable scheme, it is not permissible for the points to be run through in the trailing direction. It might appear somewhat questionable as to the desirability of installing a non-trailable scheme when safeguards can be adopted : but certain railway companies lay down strict rules regarding the bursting of points, and it is to conform to this regulation that non-trailable apparatus has been designed. At the same time efficient electric detection can be introduced so that the signalman may know exactly the state of the points should anything untoward take place during the movement of the operating lever.



Interlocking Apparatus for Wire Worked Points.

THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

PASSING PLACE SHOWING METHOD OF CONNECTING UP WIRE WORKED POINTS TO CABIN.

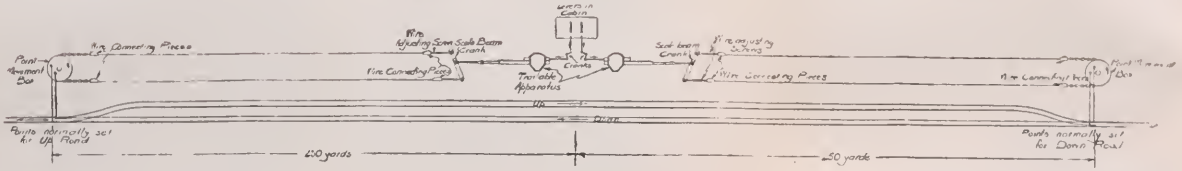


Fig. 1.
Trailable Scheme.

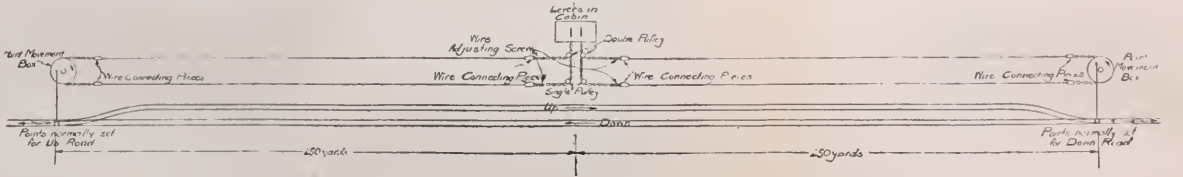
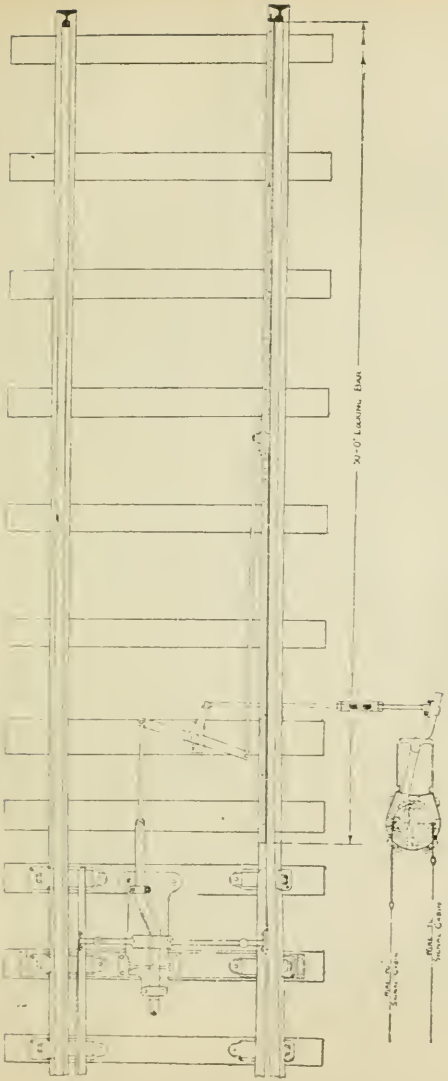


Fig. 2.
Non-Trailable Scheme.

To face page 47.



D

POINT ROD COMPENSATION.

Three typical examples will be taken and the reasoning traced. Before proceeding, with the examples it will be useful to mention a few rules in order to clearly grasp the mathematical formulæ that have been adopted in the examples following :—

Accurate compensation must take place between the signal box and the first pair of points; neglecting theoretically the second pair; then compensate accurately between the first and second pair of points as though the connection to the signal box were non-existent.

Whenever possible, compensation is best carried out by ordinary cranks, as shown in Fig. 3, as when an ordinary 2-way crank gives a reverse motion—pull to push, or push to pull—it becomes a compensator (as at B.C. in Figure 2), all compensators changing the direction of motion.

If a compensator cannot be fixed in its proper position it should not exceed 12 feet out of its original place. It is not usual to compensate for very short distances, say, under 30 feet. If, however, the point rodding is under shelter, in a station or covered goods yard, this distance may be slightly exceeded.

Two rules will now be laid down in the working out of the compensation given hereunder :—

Rule 1.—To find distance of compensator from the next crank. Take the total distance between the cranks on each side of compensator, add the lengths of all cross-rods travelling in the reverse direction to that portion of main rod adjoining crank from which measurement is to be taken ; deduct the lengths of all cross-rods which travel in the same direction to it, and divide the total by 2. See examples below.

Rule 2.—As the expansion of the rods on each side of a compensator must be equal, it follows that in Figure 1 A to D must be the same distance as E to H, and the compensator must be fixed midway between A and H. But when the cross-rod does not travel in the same direction as the adjoining main rod, the crank compensates for a portion of the main rod up to the neutral point (which is at a distance from the crank equal to the length of cross rod) and the compensator must be fixed midway between the neutral point and the other end (or the second neutral point). Then in Figure 1 H.G. must equal F.X. and the compensator J.K. fixed halfway between X and N. In Figure 3, F X. is equal to G.H., the compensator is the crank D.B. which changes the motion, and X.B. must equal C.D.

The mathematical formulæ for working out the distance for fixing of compensators for Fig. 1 are as follow :—

By Rule 1 : C.D. $= \frac{252+7-10}{2} = 124\frac{1}{2}$ yards.

E.F. $= \frac{252-7+10}{2} = 127\frac{1}{2}$,,

FIGURE 1.

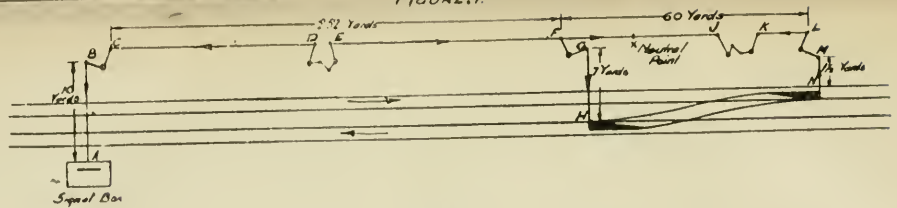


FIGURE 2.

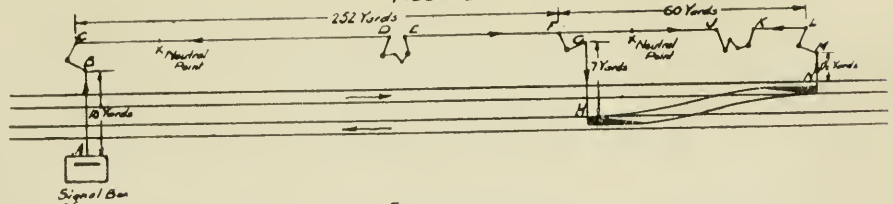
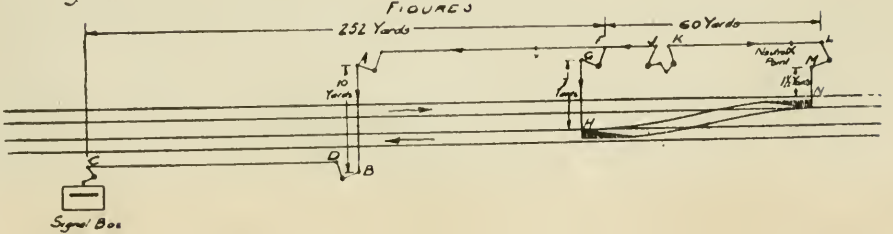


FIGURE 3



$$\text{F.J.} = \frac{60+7+1\frac{1}{2}}{2} = 34\frac{1}{4} \text{ yard}$$

$$\text{K.L.} = \frac{60-7-1\frac{1}{2}}{2} = 25\frac{3}{4} \text{ ,,}$$

By Rule 2 : A. to D. $= \frac{252+7+10}{2} = 134\frac{1}{2}$ yards.

E to H = A. to D as given above.

$$\text{F.X.} = \text{H.G.} \therefore \text{X.J.} = \frac{60-7+1\frac{1}{2}}{2} = 27\frac{1}{4} \text{ yards.}$$

K. to N. = X.J. as given above.

The mathematical formulæ for working out the distance for fixing of compensators for Fig. 2 are as follow :—

By Rule 1 : $\text{C.D.} = \frac{252+7+10}{2} = 134\frac{1}{2}$ yards.

$$\text{E.F.} = \frac{252-7-10}{2} = 117\frac{1}{2} \text{ ,,}$$

$$\text{F.J.} = \frac{60+7+1\frac{1}{2}}{2} = 34\frac{1}{4} \text{ ,}$$

$$\text{K.L.} = \frac{60-7-1\frac{1}{2}}{2} = 25\frac{3}{4} \text{ ,,}$$

By Rule 2 : $\text{A.B.} = \text{C.X.} \therefore \text{X.D.} = \frac{252-10+7}{2} = 124\frac{1}{2}$ yds.

E. to H. = X. to D., as given above.

$$\text{F.X.} = \text{H.G.} \therefore \text{X.J.} = \frac{60-7+1\frac{1}{2}}{2} = 27\frac{1}{4} \text{ yards.}$$

K. to N. = X.J., as given above.

The mathematical formulæ for working out the distance for fixing of compensators for Fig. 3 are as follow :—

By Rule 1 : $\text{C.D.} = \frac{252+10-7}{2} = 127\frac{1}{2}$ yards.

$$\text{E.F.} = \frac{252+7-10}{2} = 124\frac{1}{2} \text{ ,,}$$

$$\text{F.J.} = \frac{60-7-1\frac{1}{2}}{2} = 25\frac{3}{4} \text{ ,,}$$

$$\text{K.L.} = \frac{60+7+1\frac{1}{2}}{2} = 34\frac{1}{4} \text{ ,,}$$

By Rule 2 : $\text{X.F.} = \text{G.H.} \therefore \text{C.D.} = \frac{252-7+10}{2} = 127\frac{1}{2}$ yards

B. to X. = C.D., as given above.

$$\text{X.L.} = \text{M.N.} \therefore \text{H.J.} = \frac{60-1\frac{1}{2}+7}{2} = 32\frac{3}{4} \text{ yards.}$$

K.X. = H.J., as given above.

NOTES ON INTERLOCKING.

The interlocking of switches and signals, although not generally known outside the railway, is one of the most important branches of signal engineering, and perhaps a few notes may prove of interest on account of the very important part it plays in regard to safety in travel and also the great facility with which shunting movements can be expeditiously carried out without fear of mishap due to mechanical or electrical failure.

There are many things to be taken into consideration, *e.g.*, the nature of the layout, minimum traffic requirements and best method to give the maximum amount of train movements at one time combined with absolute security.

Broadly speaking, layouts may be divided into three heads :

A. Running roads with through shunts and siding accommodation. Single lines with passing places.
B. Junctions and level crossings.
C. Stations, termini and shunting yards.

The best way of considering each will be to take a typical example and deal with the parallel movements in each instance, and at the same time making this clear by showing the table of interlocking as reasoned out according to the movements required by the traffic department.

It must be understood that every layout cannot be ideal on account of the natural obstructions that occur, such as boundaries, buildings, etc., that prevent the laying down of better facilities.

In Figure 1 is illustrated an example of a double line of way with through shunts, siding accommodation and level crossing gates. The complete locking table is shown and it will be seen that all conflicting signals are effectively interlocked with each other, and all possible colliding or converging movements guarded against.

Figure 2 is an illustration of a passing place with Up and Down platforms. The interlocking is self-explanatory and can be followed from the locking table.

Figure 3 shows junction of branch with main line. Lock bars are shown fitted to each end of through shunt to enable a passenger train to be diverted from the up main to down branch line.

Apart from the fundamental principles governing the rules for the Interlocking of any lay-out, the same depends in a very great measure upon the local traffic requirements at any specific Signalling Installation and, therefore, it is a somewhat difficult matter to lay down any hard and fast rules with regard to saying what should, or should not, be done at any particular place.

The ordinary rules regarding Interlocking, of course, are so well-known that it seems hardly necessary to recapitulate them.

Distant Signals must be released by their respective Home, Starting and Advance Signals in the same direction.

All Conflicting Signals must interlock one another, either through themselves, or through the medium of the points and bars.

Another point to be aimed at in locking up a frame is to take care that a centre lever has not to be released by the ones on either side, which in the case of a 4-in. pitch frame, is most difficult to pull over; especially if the Signalman is short of stature—*e.g.* 2 should not be released by 1 and 3.

The whole idea of Interlocking lies in the fact that no conflicting movements can be given by the Signalman which might bring about two or more trains colliding either in a direct, converging or broad-side manner.

The following axioms might prove useful when dealing with the Interlocking between the signals, points and bars, when such occasions arise, similar to those laid down hereunder. Where the word "dead" is used, this implies, of course, absolute; "B/w" implies "both-ways" Interlocking:—

A Signal locks a Facing Bar (B/w) behind it, if the Bar is preceded by another Signal, which is released by the Bar, and thus ensures the Bar being over.

A Signal is released by a Facing Bar behind it, if the Bar is not preceded by a Signal to do the above.

A Signal locks a Trailing Bar (B/w) behind it to allow of more movement if the Bar is either a Trailing Bar to a one or two-way road on a parallel line to the one the Signal refers to. But if the Bar is a Trailing Bar to a one or two-way road on the same line it will be locked dead. This saves locking Signal with Signals facing it.

A Signal locks a Trailing Bar before it Dead.

A Signal locks Trailing Points behind it (B/w) unless one of the roads is not used for that Signal, when it locks Trailing Points dead.

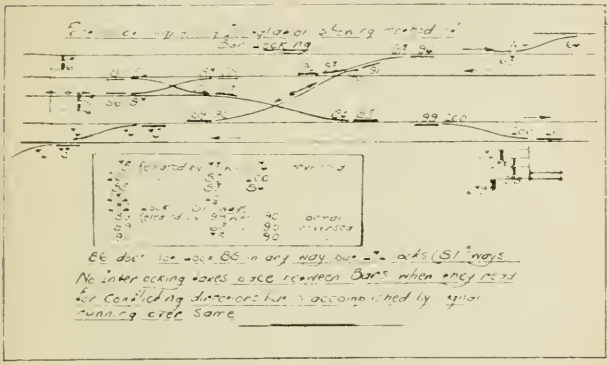
A Signal locks Trailing Points before it dead.

A Signal may be released conditionally by the Trailing Points behind it.

If the Facing Points are only the Facing end of the Cross-over Road, the Trailing end of which the Signal locks (B/w) it follows that the Facing end will necessarily be locked (B/w) as the two ends are numbered alike. But a real Facing Point with Lock Bar is never locked (B/w) by the Signal ahead of it, nor is it required to be locked at all, as the Bar does that.

The figure on page 53 shows a system of Locking Bars in connection with a portion of a lay-out, from which, by the table, it will be seen that no Interlocking takes place between the Bars when they read for conflicting directions, but is done by the signal running over same; and this appears to be the best method of dealing with rather intricate installations of this kind.

At the same time, the freedom of parallel running must not be curtailed to obtain this end, as one can, by means of special Interlocking, get the greatest facilities of running movements with absolute safety out of the lay-out that is being locked up, which is very necessary in important yard and intricate junctions.



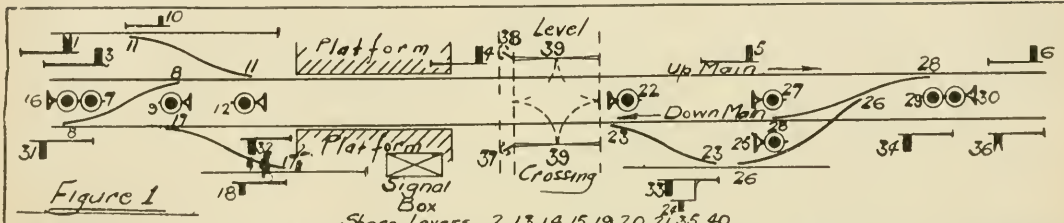


Figure 1

Spare Levers 2.13.14.15.19.20.21.35.40

No	Released by	Locks	No	Released by	Locks	No	Released by	Locks	No	Released by	Locks
1	3.4.5.6.		11		3.8.	21	Spare	Lever	31		7.16. (8.17 3/4)
2	Spare	Lever	12	11.	4.6.10.	22	23.	17.29.29.30.32.	32		8.17.23.28.29.
3		8.11.28.39.	13	Spare	Lever	23		27.33.34.39.	33		8.17.23.26.27.39.
4		9.12.28.39 (8.11 3/4)	14	"	"	24	23.	17.22.25 (26 1/2)	34		8.17.23.28.29.
5		9.12.28.	15	"	"	25	26.	24.29	36	Spare	Lever
6		29.30. (26.28 1/2)	16	17	18.31.	26	28.	27.30.33.	36	3.32.33.34.	
7	8.	9.31.	17		8.22.24.32.33.34.	27	28	23.26.30.32.33.	37		
8		3.11.17.32.33.34.	18	17	16.	28		3.4.5.34. (23 1/2)	38		
9	8.	4.5.7.	19	Spare	Lever	29	26	6.22.25.	39		3.4.23.33.34.
10	11.	12.	20	"	"	30	28	6.22.26.27.	40	Spare	Lever

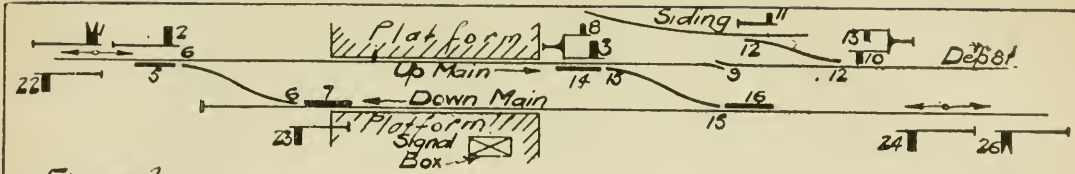


Figure 2.

Spare Levers 4.17.18.19.20.21.24.

No	Released by	Locks	No	Released by	Locks	No	Released by	Locks
1	2.3.		10	9.	2 6 8. (5.14 ⅝ in)	19	'Spare'	Lever
2	5.14.	10.22 (12 when 16 is no	11	12.	13	20	"	"
3	14.16	(16 ⅝ in)	12		9 (2 when 16 is no	21	"	"
4	Spare	Lever	13	12	11	22		2 (5⅞ in)
5		6.	14		(15⅝ in)	23	6.7.	
6		5.10.	15		9.16.	24	16.	
7		(6⅝ in)	16		15.	25	Spare	Lever.
8	9.14	10	17	Spare	Lever	26	22.23.25.	
9		12.15	18	"	"			

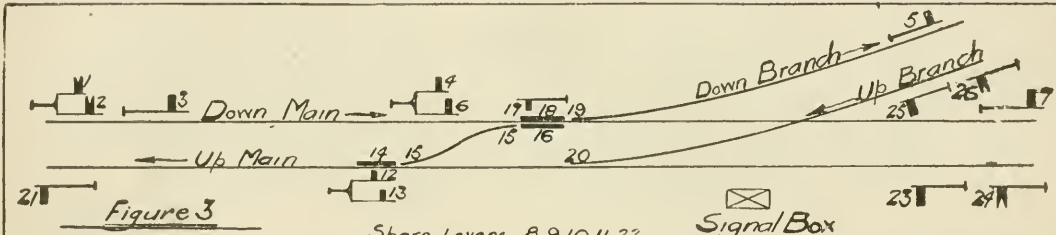


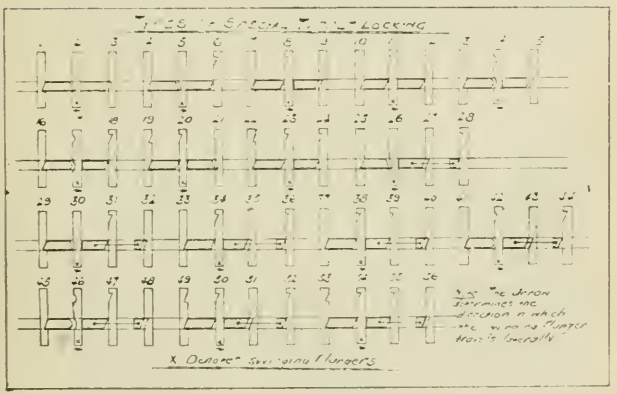
Figure 3

Spare Levers 8.9.10.11.22

No	Released by	Locks	No	Released by	Locks	No	Released by	Locks
1	3.4.		10	Spare	Lever	19		6.13.
2	3.5.6		11	"	"	20	19	13.23
3	18.	15	12	14.18.19.	17.21 (16 ft/in)	21		12.13 (14.15 ft/in)
4	18.19.	13.	13	14.18.	17.19.21 (16 ft/in)	22	Spare	Lever
5		17 (15.16 ft/in)	14	15.		23		15.20
6	18	15.19.	15		3.4.20.23	24	23.	
7		17 (15.16 ft/in)	16	15	(19 ft/in)	25	20.	
8	Spare	Lever	17	16	5.6.12.13 (14.18.19 ft/in)	26	25.	
9	"	"	18		(15.19 ft/in)			

The figure below shows types of special tappet locking for Single Plunger Interlocking Apparatus, and these should prove very useful in determining the getting out of various combinations required, these being varied as circumstances demand.

Another form of special Interlocking is that known as Self-locking, whereby, the Signalman is bound to go through certain movements, which prove to him that a train is not standing at a certain point in that section. The following is a brief description of a Self-locking installation :— This system of Interlocking has been designed to deal effectively with rather difficult conditions laid down in respect of Self-locking, where a lever cannot be pulled over in the Signal Frame until another lever has been operated to its full extent, and when the former has been put back to its normal position, it becomes self-locked, and cannot be again pulled until the other lever has been put back to normal.



Interpretation of Special Locking shown in Figure
1 locks 2 when 3 is over . 2 locks 6 when 7 is over and 8 is normal
4 . 5 . 6 . normal 29 . 30 . 31 . normal 32 . over
7 released by 8 . 9 . over 33 released by 34 . 35 . over . 36 . normal
10 . . 11 . 12 . normal 37 . . 38 . 39 . normal 40 . over
3 locks 13 & 14 . 15 . over 41 locks 42 & 43 . 43 . over . 44 . normal
16 . 17 & 18 . normal 45 . 46 & 47 . 47 . normal . 48 . over
19 released by 20 & 21 . over 49 released by 50 & 51 . over 52 . normal
22 . . 23 & 24 . normal 53 . . 54 & 55 . 55 . normal and 56 is over

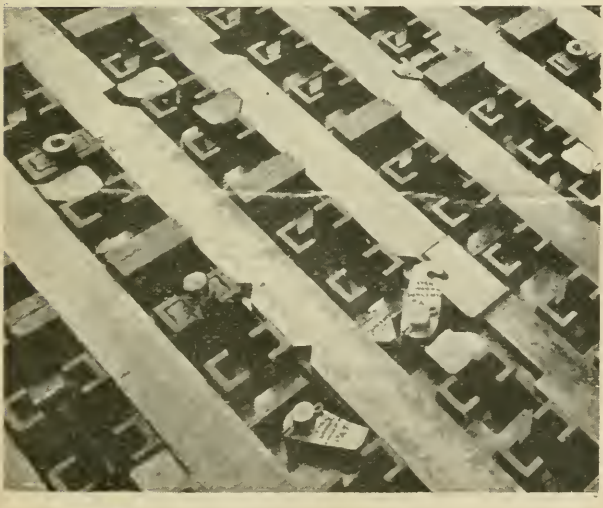
Assuming for instance, that a signal lever and a fouling bar lever are to be interlocked under these conditions, three parallel bridle bars are arranged at right angles to the lengths of the levers and are connected by a beam lever centred on the middle bar, each end of the beam being held between blocks secured to the inner and outer bridle bars respectively. If the outer bridle bar is locked, any longitudinal movement of the inner bar will carry with it, though to a less extent, the middle bar. If the inner bar is locked, a longitudinal movement of the middle bar will cause a displacement in the same direction of the outer bar. The signal lever is locked in the normal position, for example, by a pawl engaging in the ratchet teeth of a plunger attached to this lever.

Before the signal lever can be released, the fouling bar lever must be pulled over; suitably disposed bevelled blocks on a plunger of this lever then displace the inner bridle bar and with it through the beam lever the middle bar, the upper bridle bar being locked by the abutment of a block secured to it against a projection of the said plunger. The displacement of the middle bridle bar releases the pawl, when the fouling bar has been pulled over to its full extent and allows the signal lever to be pulled over, whereupon by the action of a suitably disposed bevelled block on the plunger of this lever, the middle bridle bar is moved back to its original position and carries with it the outer bar, the inner bar being now locked against movement and acting as the fulcrum of the beam lever. The backward displacement of the middle bar causes the pawl to again engage with the ratchet teeth on the plunger of the signal lever. When the signal lever is restored to its normal position, the pawl is still in engagement with the ratchet teeth and the lever is locked, even if not put back fully to its correct position, and cannot be again released until the fouling bar lever has been returned to normal or again pulled over. Blocks disposed on the signal and fouling bar levers engaging with grooves in the bridle bars prevent any displacement of these bars, when the locking blocks have left their respective abutments.

When the fouling bar lever is restored to normal, the bridle bars are returned to their original positions.

Instead of connecting the bridle bars by a beam lever, a roller may be inserted between inclined surfaces of members operated by the bevelled surfaces of blocks secured to the inner and outer bridle bars, the rollers abutting with one end of the middle bridle bar.

This form of Tyer's Self-lever locking can also be adapted —not only to Duplex Plunger Interlocking Apparatus on which this locking is now fixed, but to direct plungers, cam triggers, or other types of mechanism for operating levers.



Tyer's Patent Special Interlocking Mechanism.

INTERLOCKING FRAMES.

Types of Locking.—There have been many kinds of interlocking in use at different times on the railways of Great Britain, but locking on the tappet principle has outlived all other kinds and may be truly said to be the survival of the fittest.

Figs. 1 and 2 illustrate the method of tappet locking. The channels in which the tappets lie are omitted for clearness. Tappet locking is readily adaptable to the requirements of special locking, which is commonly effected by allowing one or more plungers to slide laterally. Such plungers, however, cannot do any other locking, and hence sliding plates or tappets are often employed. Fig. 3 shows examples of special locking employing loose and sliding tappets. In other types, L-pieces and special swinging pieces are used (Fig. 4).

Another class of locking is known as "check locking," its purpose being that after a certain lever has been reversed and put back, it cannot be pulled again until another lever has been reversed and put back. It may be applied to home and starting signal levers, but must then be provided with a releasing key.

Actuation of Locking.—There are two alternative principles on which the interlocking in a frame is actuated. One is preliminary latch-locking or catch-handle locking, and the other is lever-locking. In the first system, all the necessary conflicting locking is done before the lever itself is moved at all, while levers to be released are not freed until the releasing lever is not only reversed, but properly latched, and undue pressure cannot be put on the interlocking, because the signalman, being unable to lift the catch, is unable to move the lever.

The principal advantage of lever-locking is that the operating mechanism is stronger and more substantial, while in very big frames the required travel can be imparted to the interlocking with much greater ease. This system is that principally employed in Great Britain.

In America, manual interlocking machines are almost wholly of the preliminary latch-locking type.

Travel of Plungers.—When the plungers are operated directly off the lever, it will not generally be possible to arrange for more than two rows of locking channels, or at the most three, owing to the difficulty of spacing the notches so as to ensure that no wrong tappets enter and prematurely lock the lever. The usual preventive method adopted is to make the tappets in the adjoining channels different sizes.

The difficulty will, however, entirely disappear if the travel of the plunger is short and less than the pitch of the channels, but this reduced travel cannot be obtained by placing the plunger low down on the lever, as the

locking would be smashed by the enormous leverage that could be exerted upon it. The plunger must therefore be connected to the lever high up and reducing travel device employed.

Position of Lever in Latch-Lockihg.—In frames employing preliminary latch-locking, it is essential that the mechanism registers the actual position of the lever, *i.e.*, that it ensures that the lever is correctly normal or reverse, as the case may be. The methods adopted vary and are described later.

Pitch of Levers.—The pitch of the levers ranges from 4 in. to 6 in. Although 6 in. pitch gives more space to the signalman, it is unquestionably better to adopt a 4-in. pitch in order to reduce the total length of the frame

Essential Features.—To secure an efficient interlocking frame, there are several points to be remembered. It should have :—(*a*) The simplest possible construction ; (*b*) As few pins between the locking and latch-handle (or lever) as possible ; many pins eventually mean "lost motion," which results in slack locking ; (*c*) Interlocking easily and quickly, accessible for inspection, cleaning and repairs ; (*d*) Large wearing surfaces ; (*e*) Strict interchangeability and independency ; this greatly facilitates alterations and extensions.

TYPES OF INTERLOCKING FRAMES.

Tyer & Company (English and Colonial Patterns).—Messrs. Tyer & Company manufacture both duplex and single plunger types of interlocking frames, their well-known 1909 single plunger type (Fig. 4a) being used practically throughout the whole of the Straits Settlements. The great advantage of the single plunger 1909 pattern is the fact that owing to the lever being fixed in a shoe it can easily be detached if necessary and taken out without interfering with any other part of the frame. Another great feature of this frame is the ease with which electric locking apparatus can be fixed thereto for lock and block working, etc. Messrs. Tyer have also a very neat arrangement with regard to electric locking where their ground frames are employed, and the illustration (Fig. 4b) shows this quite clearly.

Saxby & Farmer (English Pattern).—Fig. 5 illustrates the Saxby & Farmer duplex plunger catch-handle locking frame. Two plungers are fitted one above the other in each locking channel.

The upper plunger is connected directly to the lever, but is too low down for effective locking, being merely to register the correct position of the lever. The lower plunger is actuated by the latch and does the locking. Without the registering plunger the latch could be locked in the wrong position.

The pitch of the levers is 4 in.

American Pattern.—Saxby & Farmer interlocking machines are very largely used in the United States, and a peculiar form of tappet locking is employed in conjunction with the well-known slotted plates and rockers (Fig. 6). The locking bars are driven by drivers attached to the rockers and the interlocking is effected by "dogs," which are riveted to the locking bars, engaging with cross locks.

Figs. 7 and 8 show a Saxby & Farmer " dog " chart. The horizontal lines represent locking bars, the small circle drawn on the line showing by which lever the bar is worked and where the connection is made. The cross locking is represented as being placed close to the " dog " by which the locking is performed. For special locking, a swing " dog " is employed (Fig. 8).

It may be mentioned that this type of interlocking is also used in the Westinghouse electro-pneumatic interlocking frames.

McKenzie & Holland.—For many years the standard frame of this firm was the well-known cam and shaft type employing lever-locking. A great advantage was claimed for it in the ease and readiness with which a lock could be added or removed without interfering with the rest of the interlocking. Tappet lever-locking is employed in their present standard frame, travel being imparted to the plunger by a cam (Fig. 9.) The total travel is $2\frac{1}{4}$ in., made up of two travels of $1\frac{1}{8}$ in. The levers are 4 in. pitch.

Dutton.—This pattern frame employs catch-handle locking and only one plunger instead of two, as in the Saxby & Farmer frame. Travel is imparted to the plunger from the latch by means of a slot and sliding pin. The total travel of the plunger is $1\frac{3}{8}$ in. and the pitch of the locking channels $2\frac{1}{4}$ in. The latch-handle is large and powerful and the locking troughs are inclined at an angle of 45°, which greatly facilitates examination or alteration.

Great Western Railway.—Figs. 10 and 11 illustrate the standard tappet locking frames used on this railway. The travel of the plunger is reduced by the cam to $1\frac{1}{2}$ in. made up of two travels of $\frac{3}{4}$ in. and the pitch of the locking channels of $1\frac{7}{8}$ in. The cam plate and stud are mild steel and the stud bearing plates gun-metal, an arrangement which has ben found to give remarkably little wear. The pitch of the levers is 4 in., although $5\frac{1}{4}$ in. is occasionally used.

London & North-Western Railway.—The Webb interlocking frame, which was formerly the Company's standard frame, is still in extensive use on that system. A form of stud locking arranged vertically is employed, actuated by a tumbler on the lever-locking principle. In the present standard catch-handle locking frame tappet locking is used.

The catch employed (Fig. 12) is peculiar both in design and operation, no spring being employed. The signalman depresses the handle to raise the latch and when he afterwards releases the handle, the latch falls into the correct position by its own weight. The latch is in the form of a heavy drop box which engages with a radius plate on the quadrant.

North Eastern Railway.—This Company's frame is a good example of a class of locking frame in which the plunger is driven directly off the lever without any reducing travel device (Fig. 13). The stepping arrangement of the locking troughs allows of easy inspection. The tappets are of different shapes for each channel to avoid conflicting notches and tappets.

The Railway Signal Co.'s and Stevens & Sons' frames are also of this class.

MAINTENANCE.

Interlocking frames require periodical overhauling and cleaning, but it is impossible to lay down any rule as to how often this must be done, because circumstances are so different. In some manufacturing districts the state of the atmosphere is such that very frequent cleaning is required, while at big centres the frames require frequent cleaning and overhauling on account of the heavy work to which they are put. The Signal Inspector, being well acquainted with the conditions in his district, should be made responsible for seeing that the frames are cleaned as often as may be necessary and that the locking is kept correct and in good working order.

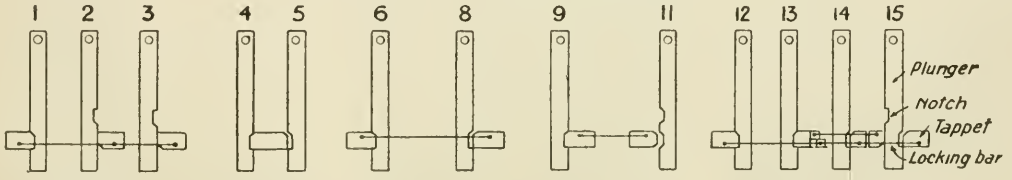
FIG I.

STANDARD FORM OF LOCKING TABLE
ENGLISH STYLE

LEVER NO.	RELEASED BY	LOCKS NORMAL	LOCKS BOTH WAYS	RELEASES
1	2. 3			
2		14. 17. 19. 30.		1
3	(18 OR 23)	15. 18. (25W 19. 21R)	14. 17	1
4	18	(27W 16N)	13	
5	SPARE SPACE			
ETC				

Note: (27W 16N) may also be written (27W 16) and (25W 19. 21R) may also be written (25W (19) (21))

EXAMPLES OF TAPPET LOCKING.



1 Released by 2 and 3

4 Locking 5 and 5 Locking 4.

6 Locking 8 and 8 Locking 6

9 Locking 11 both ways.

12 Locking 13 14. 15. 13. Released by 15

FIG. 2.

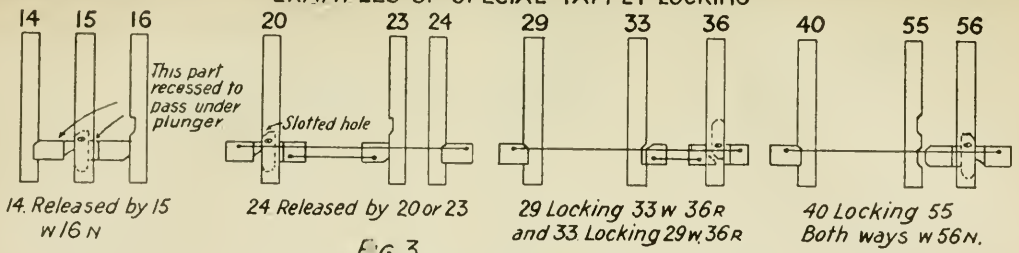

EXAMPLES OF SPECIAL TAPPET LOCKING
14
15
16
This part recessed to pass under plunger
20
23
24
Slotted hole
29
33
36
40
55
56
14. Released by 15 w 16 N
24 Released by 20 or 23
29 Locking 33 w 36 R and 33 Locking 29 w 36 R
40 Locking 55 Both ways w 56 N.

FIG 3.

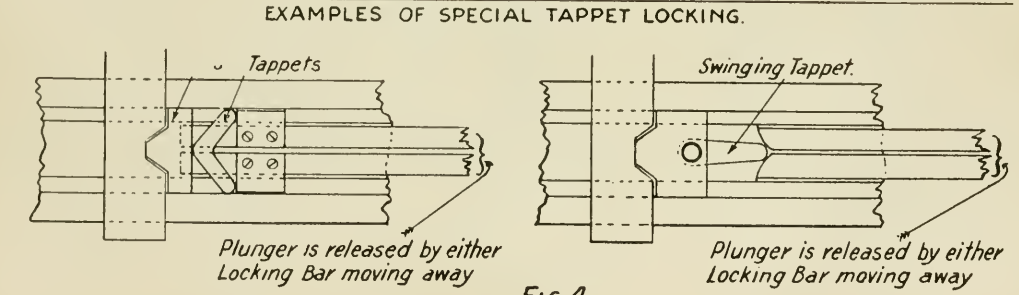

EXAMPLES OF SPECIAL TAPPET LOCKING.
Tappets
Swinging Tappet.
Plunger is released by either Locking Bar moving away
Plunger is released by either Locking Bar moving away

FIG. 4.

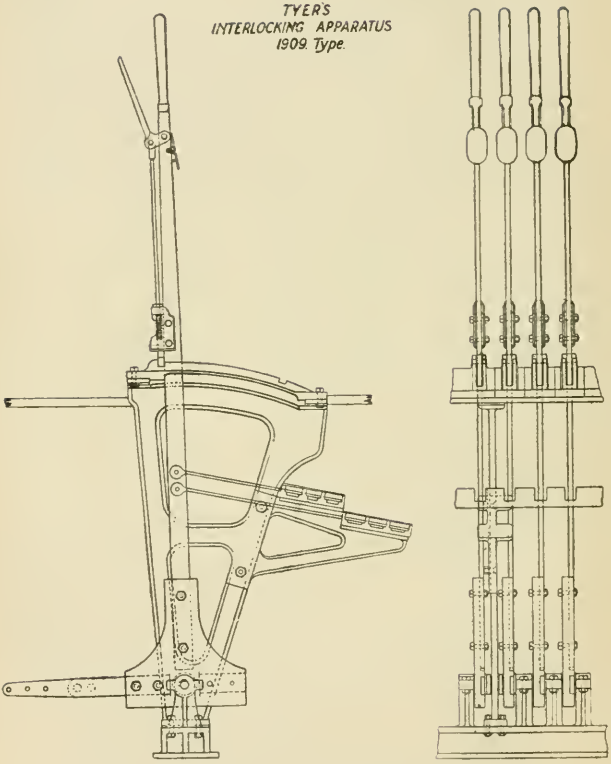


Fig. 4a.

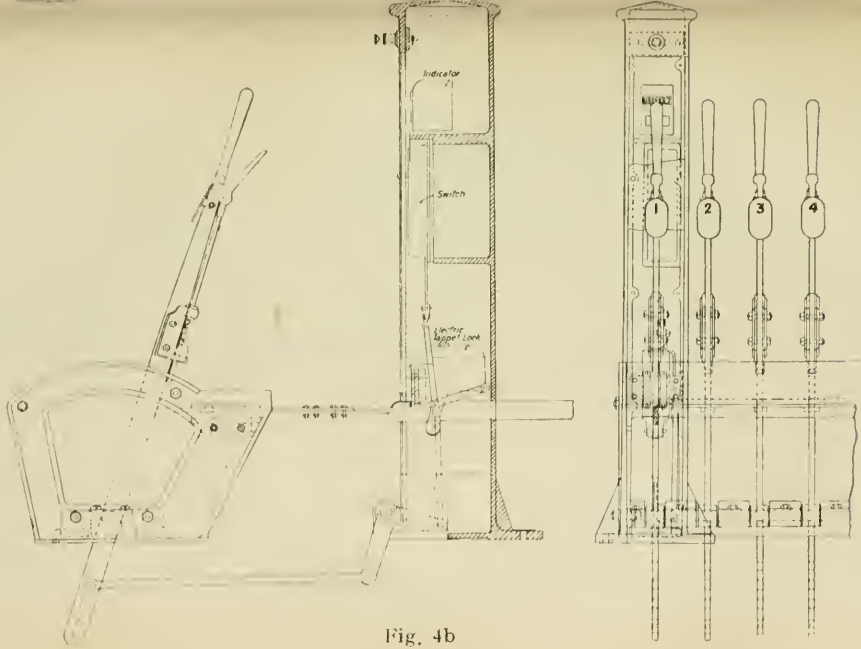


Fig. 4b

NEW SPLIT ROCKER FRAME.

A very neat and efficient locking frame embodying catch handle locking has been devised by Messrs. Tyer & Company, which includes a split rocker, this allowing a very free and easy motion in operating the levers. A brief description of working is as follows :—

Raising the Catch Rod lifts the rocker into a true radius for the die to pass through slot in rocker and moves the locking plunger half stroke. Fig. A shows the lever in its normal position. Fig. B, the lever half over; and Fig. C, the lever in the over position with the locking completed. The travel of the plunger is less than the distance between the channels, and therefore, one notch cannot enter another channel. Two types of locks only are necessary for ordinary locking. The plungers can be withdrawn, cut and replaced without removing the covers or disarranging the locking, allowing alterations to be made while traffic is in progress.

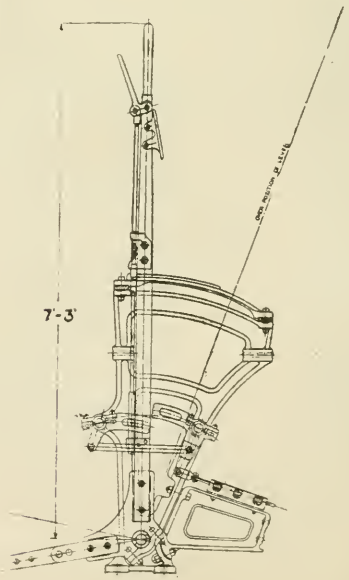


Fig. A.

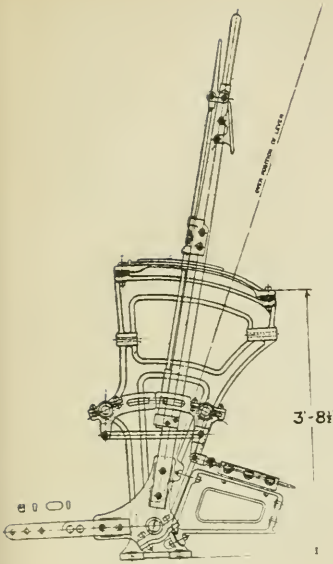


Fig. B.

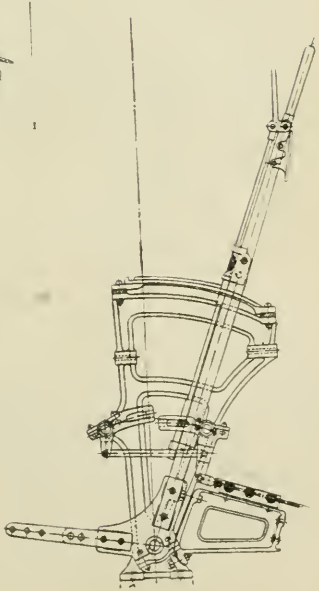


Fig. C.

SAXBY AND FARMER DUPLEX PLUNGER INTERLOCKING FRAME.
Tappet Locking.

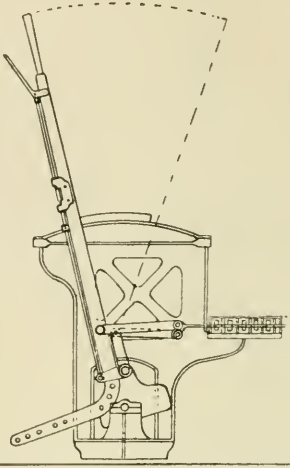


Fig. 5.

SAXBY AND FARMER INTERLOCKING MACHINE
Arranged for Vertical Leadout *Tappet Locking*

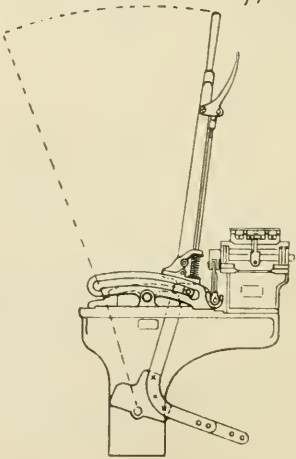


Fig. 6.

STANDARD FORM OF LOCKING SHEET.

American Style
FIG. 7.

REVERSE	LOCKS
1	(2)
2	(6). 7. 10.
3	(6). 11
W	(7) x 10
4	SPARE LEVER
5	SPARE SPACE
6	7. (7)
7	
8	SPARE SPACE
9	SPARE LEVER
10	(6)
11	(6). 7
12	(11)

KEY

(2) = 2R

W(7)x10 = (10W 7R)

7 = 7N

The Dog Chart for the above is shown on Fig 8

SAXBY AND FARMER. DOG CHART.

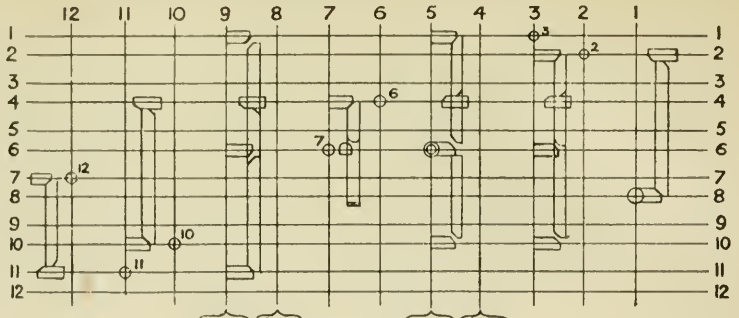


Fig. 8.

Direction of Travel of Locking Bars when Levers are being reversed.

Mc KENZIE & HOLLAND CAM & TAPPET INTERLOCKING FRAME

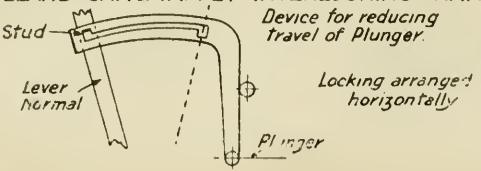


Fig. 9.

G.W.R. STANDARD INTERLOCKING FRAME

Tappet Locking.

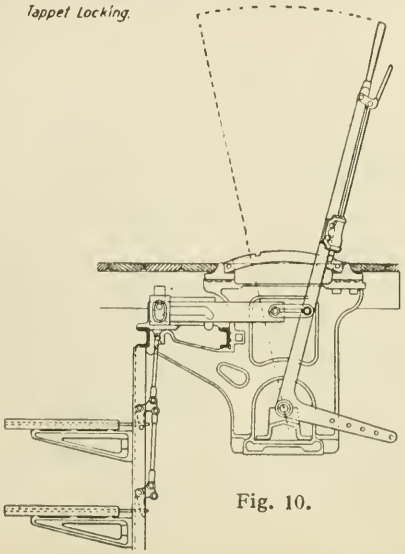


Fig. 10.

G.W.R STANDARD INTERLOCKING FRAME

Tappet Locking

This type is employed instead of that shown in FIG 10 for frames of 60 Levers and under

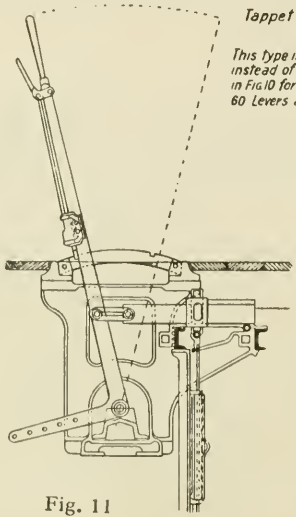


Fig. 11

L&N.W.R. TYPE OF CATCH-HANDLE

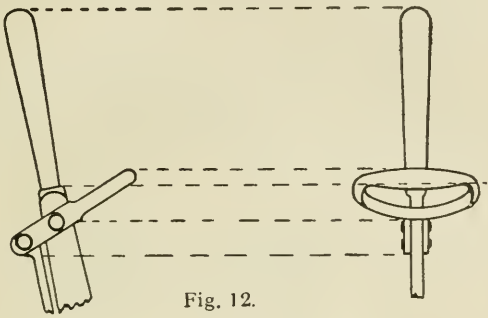
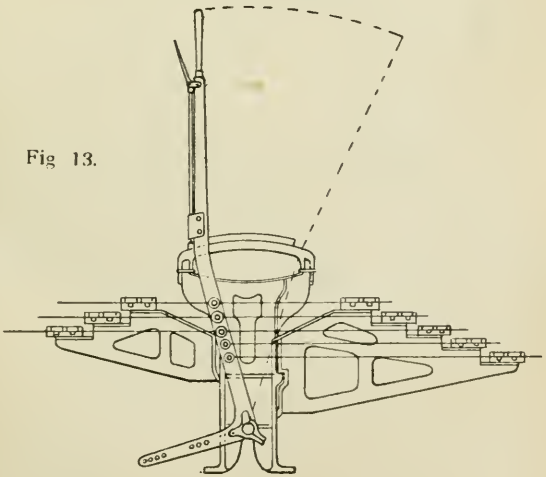


Fig. 12.

N.E.R. STANDARD INTERLOCKING FRAME.
Tappet Locking.

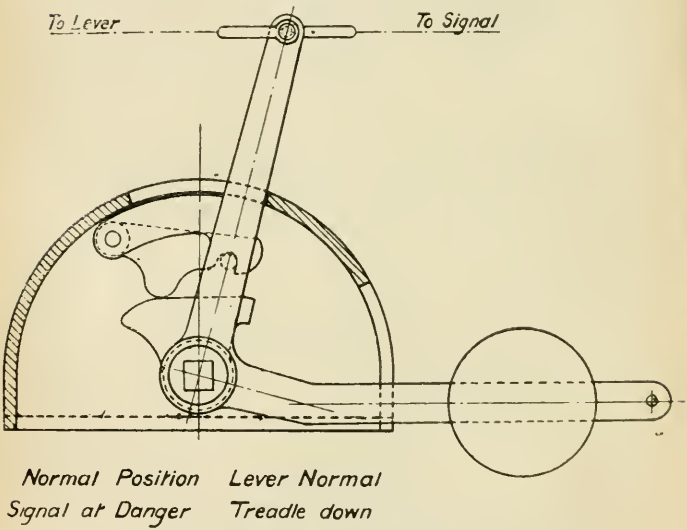
Fig 13.



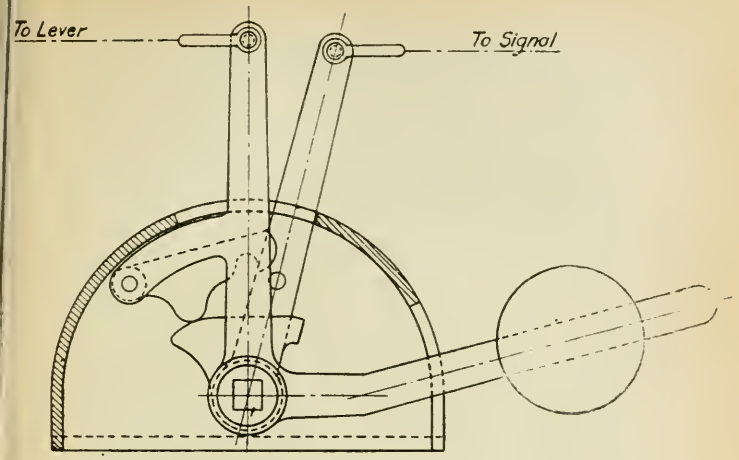
SIGNAL REPLACERS.

It is often necessary and desirable that a signal be placed to danger immediately the train has passed it, irrespective of the signalman putting back his lever in the frame. This can be achieved either electrically or mechanically. A mechanical type introduced by Messrs. Tyer is illustrated.

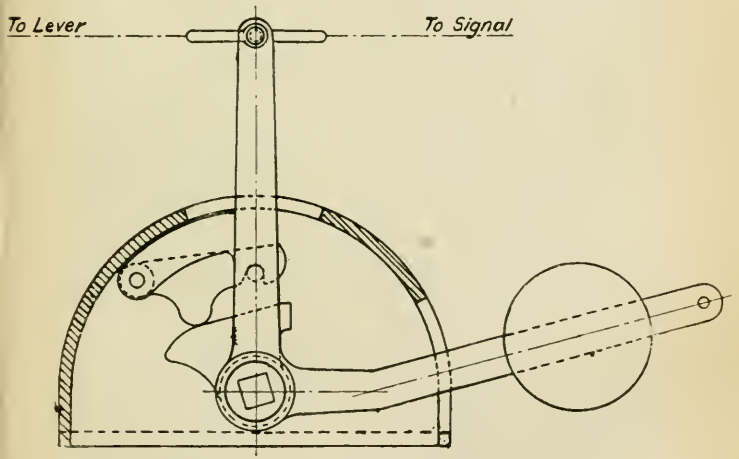
A feature of the apparatus is that after the first wheel of the train has passed over the spring treadle, the latter keeps down and does not spring up to be hit by every wheel of the train, and the replacer is ready again for action after the signalman has put back his Signal Lever to normal in his cabin.



Mechanical Signal Replacer.



Position after Operation of Treadle by wheel of train
Lever pulled Signal at Danger Treadle down



Over Position Lever pulled
Signal Off Treadle up

Mechanical Signal Replacer.

POWER SIGNALLING.

The use of power to operate points and signals is rapidly increasing.

Complete power-operated signalling systems are supplied by

Westinghouse Brake & Saxby Signal Co., Ltd.
British Pneumatic Railway Signal Co., Ltd.

A system in which the signals are power operated and the points by manual effort, is supplied by

W. R. Sykes Interlocking Signal Co., Ltd.
Westinghouse Brake & Saxby Signal Co., Ltd.

The power used is usually either electricity solely, compressed air controlled electrically, or wholly low-pressure air. The first-named is known as the "All-electric" system, the second the "Electro-pneumatic" system, and the last the "Low-pressure pneumatic" system. On the Continent there are also systems in use employing hydraulic power solely.

The advantages of power-operated systems over manual systems are

(*a*) One Signal Box can be used where two or three manual boxes would be required.

(*b*) The yard is kept clear of rodding and wires, making it safer for shunters, etc.

(*c*) The physical effort on the part of the signalman is reduced to a minimum, enabling him to concentrate his attention more readily on his work.

(*d*) A Signal Box can be placed in a position which it would not be possible for a manual box to occupy.

(*e*) The Board of Trade allows facing points with power systems to be 300 yards from the box instead of 250 yards, which is the maximum with manual systems, thus enabling greater latitude when laying out the yard.

The question as to which is the superior power to use is still a matter of opinion. Perhaps the better way to decide this question is to consider the local conditions in each case thoroughly.

Where there is an ample, reliable and cheap supply of electricity available which can be readily transformed to the required pressure, and very cold weather may be expected in the winter, an All-electric system could be selected with safety.

At stations where a plentiful, steady and cheap supply of compressed air is to be obtained and no electricity, and mild or equable weather is usually experienced throughout the year, an electro-pneumatic system would have strong claim.

Whether all-electric systems are more reliable than electro-pneumatic depends largely on the system selected. Electro-pneumatic systems are simple and the makers have had the advantage of many years' experience with them. Some all-electric systems are extremely complicated, and have not been designed with a view to making the tracing and clearing of faults an easy matter, and are of comparatively recent introduction.

The Westinghouse electro-pneumatic system is supplied by Westinghouse Brake & Saxby Signal Co., Ltd.

The lever and interlocking frame is of the type shown in Fig. 14. The small levers operate the locking gear and also rotate a shaft upon which electrical contacts are mounted.

The block instruments can be arranged on the shelf at the back of the levers.

The points (Fig. 15) are operated as follow, the road being, of course, either normal or reverse, and the signals " on."

The partial movement of the point lever rotates the contact bar in the frame, which closes a 12 D.C. circuit to an electro-magnet air valve. This valve allows compressed air at 70 lbs. per square inch to enter a cylinder and move a piston coupled to a rod connected to the point mechanism. The lock bar is first lifted, and the bolt withdrawn ; the points are moved over and bolted again, and a return indication contact made, which closes a circuit to the box and releases the check lock. The stroke of the point lever may then be completed and the interlocking released.

The compressed-air valve remains open the whole time, and the points are held in position by the air pressure.

Constant detection is employed, which means that the return indication current must be constantly received at the box, otherwise the interlocking cannot be released. Should the points be run through, the detection contacts will be forced apart and the current to the box will fail. This would cause electric locks on all the point levers to fail, and in consequence no movement of any points or signals could take place. At the same time, the current would be cut off from any signals which might be off, causing them to return to " Danger."

The electric locks cannot be restored without the assistance of a lineman. This ensures the points receiving attention before the locks are restored. An additional refinement sometimes fitted is an electrically illuminated indicator, which informs the signalman whether his points are normal or reverse.

For trailing points a simple mechanism is adopted : the piston is coupled direct to one of the point tongues, and the detector is operated by a connection to the running tongue Constant detection is, of course, employed.

The signals and discs are operated by compressed air motors, the valves being controlled electrically (Fig. 15).

Discs are locked so that they cannot be pushed off.

Any failure of electricity or air puts the signals to "Danger" and prevents the interlocking from being actuated.

When track circuits are installed in connection with the Home signals, a special electrical relay is introduced which ensures the signals remaining at "Danger" after they have assumed that position in consequence of the track having been occupied. The signalman is compelled to put the signal lever fully back before the signal can again be pulled off.

Electro-pneumatic signalling systems of this type are installed on :—

North-Eastern Railway.
Metropolitan District Railway.
London Electric Railway, and at
Glasgow, Central Station, on Caledonian Railway, Slough, Bath Road Junction on Great Western Railway.

The adoption of the upper quadrant signal (Fig. 16) in the place of the common lower quadrant arm is usual in modern power signalling installations. The advantage of the former is that the weight of the arm itself causes it to drop to the "Danger" position, whereas with the usual form of arm, a counterbalance weight, such as an extra heavy spectacle casting, has to be attached to it to ensure it returning to "Danger" in the event of a breakage of rods or wires.

ALL-ELECTRIC SYSTEMS.

One of the largest all-electric signal installations is that belonging to the Great Western Railway at Birmingham (Snow Hill Station).

There are two Signal Boxes, one containing 224 levers, 189 working, 35 spare, and the other 96 levers, 75 working, 21 spare.

The electricity used is direct current at 140 volts, obtained from the Birmingham Corporation as alternating current and converted by the G.W.R. Two 300 A.H. accumulator batteries are installed, one being used at a time to furnish signalling current.

The locking frames are comparatively small, the pitch of the levers being 2 in. and their height overall 48 in. (Figs. 17 and 18).

The levers are not fitted with catch rods. They operate the power switches on the frame through rods, and the locking gear is also directly coupled to them.

The check-lock is provided, and in one box outside detection is arranged, but in the other constant detection

has been installed. With outside detection, the signal motor circuits are led through the point detectors to which they refer. Each signal is detected as far as the next in advance.

With the constant detection, the current through the detectors at points returns to the box and operates a route switch which closes the signal circuit as well as releasing the check-lock.

In the event of points becoming deranged, the detector breaks the circuit, which in turn releases the route switches and causes signals to remain or go to " Danger."

A ½-H.P. direct current motor is employed to move facing points (Fig. 19). This is mounted on a cast-iron box resting on the sleepers supporting the rails The motor by worm gearing and a friction clutch drives a disc through 320 degrees. On this disc is a pin, which is inserted in the end of a rod. The rotation of this disc imparts a forward and then backward movement to the rod. The other end of the rod is attached to a lever fixed to a shaft lying at right angles to the rails. The shaft in turn rocks and then returns to its original position. The locking bars and plunger are coupled to another lever attached to this bar, and so are moved by it.

The points are moved over by an escapement crank.

It is possible to reverse the motor at any position of the points.

There is one detector for both tongues and the plunger, and until all contacts are " making " a check lock cannot be obtained.

For trailing points a ½-H.P. direct current motor is used, and a crank moving through 150° is coupled direct to them.

The friction clutches provided take up the momentum of the motor when it comes to the end of its travel, and also in the case of trailing points allows them to be run through without damage to the point-operating mechanism.

The semaphore signals (Fig. 20) are moved by electric motors mounted in cast-iron boxes on the signal post. A magnetic clutch couples the motor to the signal rod and the motor through worm gear can only move the signal " off " when current passes through the clutch. This holds the signal arm " off " and upon the current failing the arm returns to " Danger."

The motor switches and detector contacts are mounted in a separate cast-iron box on the post, and a rod from the arm provides the necessary movement.

All signals are lighted by 110-volt lamps, one to each signal. Alternating current from the city supply is used for signal lighting.

Another important all-electric system is the Crewe System in use on the L. & N.W.R.

Direct current at 100 volts from the Local Supply Company is employed.

There are in use frames possessing 350, 152 and 95 levers. One strong feature of this system is the simplicity and substantial proportions of its parts.

The lever frame is arranged in two tiers, the upper row of levers being for points and the lower for signals.

The locking gear switches and check-lock magnets are available for inspection and maintenance underneath the box.

The points are moved by a reversible electric motor taking 2 K.W. for about 3 seconds. These motors run in ball bearings and drive a cam wheel through a worm wheel and one direction clutches. The worm wheel runs loose on the cross shaft to which the cam wheel is attached, and by means of the above clutches the shaft is caused to rotate. A striking gear throws the clutches out of action.

In the grooves in the side of the cam wheel, rollers work attached to bell cranks. One crank works the points and the other the bolt and locking bar.

The whole mechanism runs in an oil bath A long stroke electro-magnet requiring 1·5 K.W. is used to pull off a signal and 2 ampères holding-off current is employed. By switching off the current the signal goes to " Danger " A similar device is used for dwarf signals and discs.

Electric lamps are employed on the signals.

ELECTRO-MECHANICAL SYSTEMS.

At Victoria Station, London (L.B. & S.C. Railway), a system of signalling is employed which was installed by Messrs. Sykes in 1909. A similar, but much older, installation at Glasgow (St. Enoch's) consists of six Signal Boxes containing in the largest box 88 ordinary frame levers and 400 electrical frame levers.

Direct current from 300 A.H. accumulators at 64 volts is employed. The locking and lever frame is arranged with the manual levers for working points and locks in the standard manner. Above these levers, in the place usually occupied by the block instruments, the electrical slides are fixed. These consist of narrow bars fitted with a vertical handle. The signalman pulls the handle towards him two inches for " normal " to " reverse," or pushes it in, when setting the signals to " normal."

NOTES ON THE MAINTENANCE OF SIGNALLING APPARATUS.

MANUAL SYSTEMS.

All pins and bearings should be oiled and cleaned regularly on bell cranks, locking and fouling bars, facing and trailing points, pulley wheels and levers. It is not necessary or desirable to oil or grease the roller guides or rodding.

A staff of men should be employed to do this work, and they should be provided with scrapers (for getting sand and dirt out of the awkward corners), oil feeders and good hand brushes.

Signal wires and stays for posts should be regularly inspected and worn or rusty places watched and the wire replaced should a weak spot develop.

A good maintenance system should aim at securing an absence of delays to trains due to failures of the gear.

In severe frost, salt should be sprinkled on the moving parts to prevent them becoming frozen up.

ELECTRO-PNEUMATIC SYSTEMS.

All valves, contacts, relays, etc., should be regularly examined and cleaned. Bearings and pins at signals, discs and points should be cleaned and oiled The air pipe and route should be watched and seen that it is not injured or displaced by permanent way men when relaying or ballasting is in progress.

If possible, an insulation test of each wire should be taken every six months, and the result carefully booked.

(For remarks as to the electric power plant, see the following section).

If the air pump is operated by another department it is a good idea to have a contact fitted to the air pressure gauge hand, which causes an alarm bell to ring when the pressure drops to a certain figure.

A portable voltmeter reading to 0-15 volts D.C. is essential to enable faults to be readily traced.

ALL-ELECTRIC SYSTEMS.

The previous remarks as to careful and regular cleaning and oiling of moving parts equally apply here.

A knowledge of direct current power work is essential, to enable faults to be cleared readily.

The motors should be regularly examined and any water or moisture removed from the interior of the cast-iron boxes. The commutator and brush gear flexibles to the brushes, leads and brushes into the motor box should also be inspected and adjusted if necessary. Commutators should be kept clean.

Detector contacts must not be allowed to become bent or worn unduly before replacing, and damp must be rigidly excluded.

Condensation sometimes takes place in unventilated boxes, and these must be carefully watched.

The contacts on the switches in the locking frame require regular inspection, as they have a lot of work to do.

Loose ends of coils of all kinds need watching.

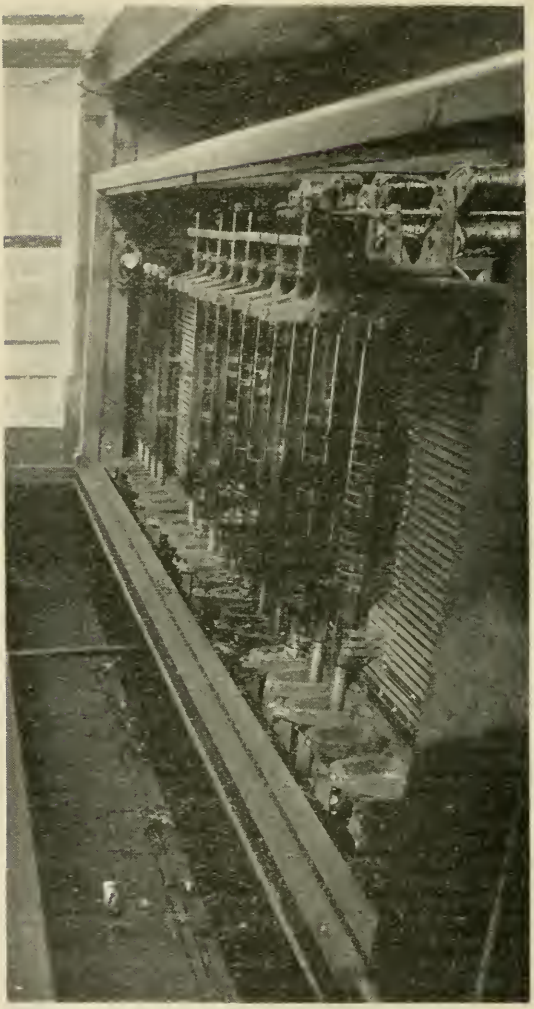


Fig. 14.

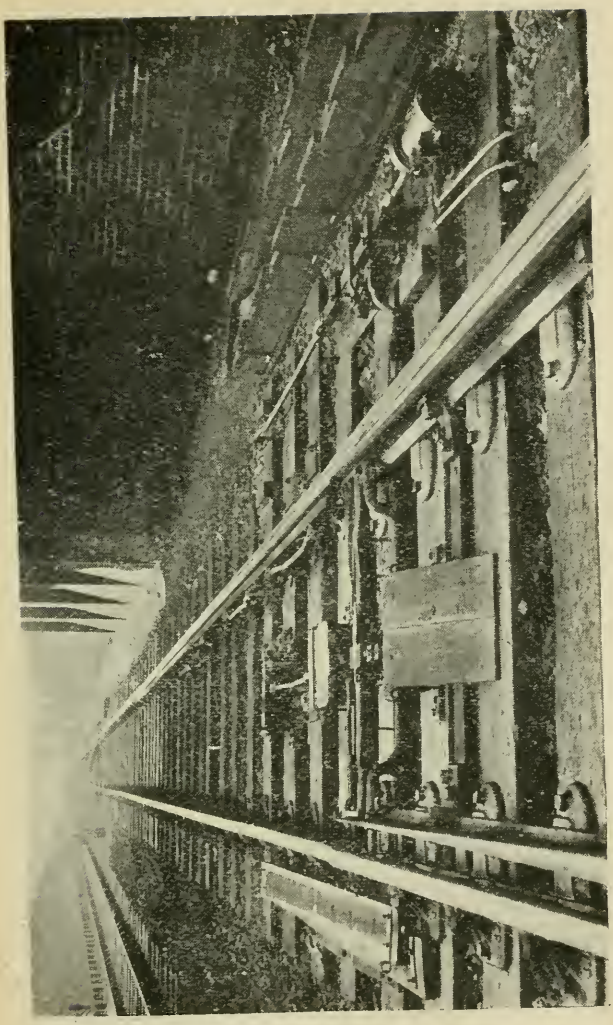


Fig. 15.

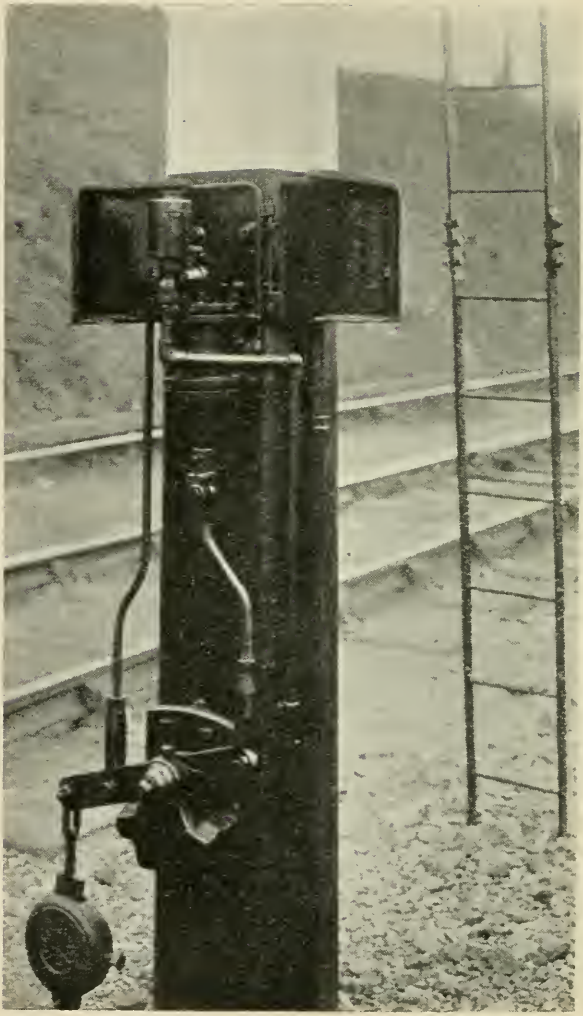


Fig. 16.

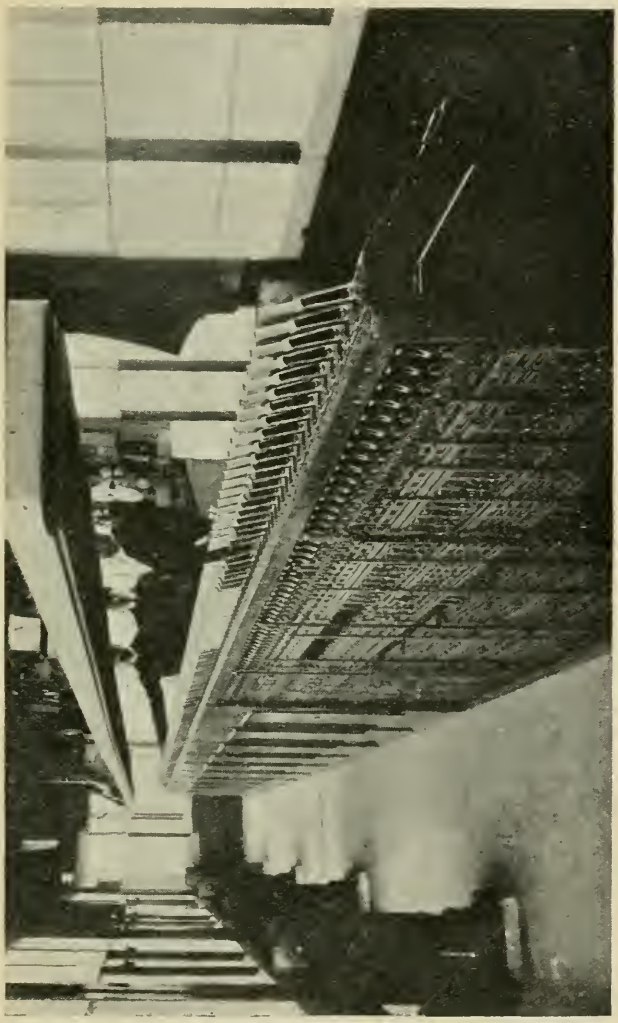


Fig. 17.

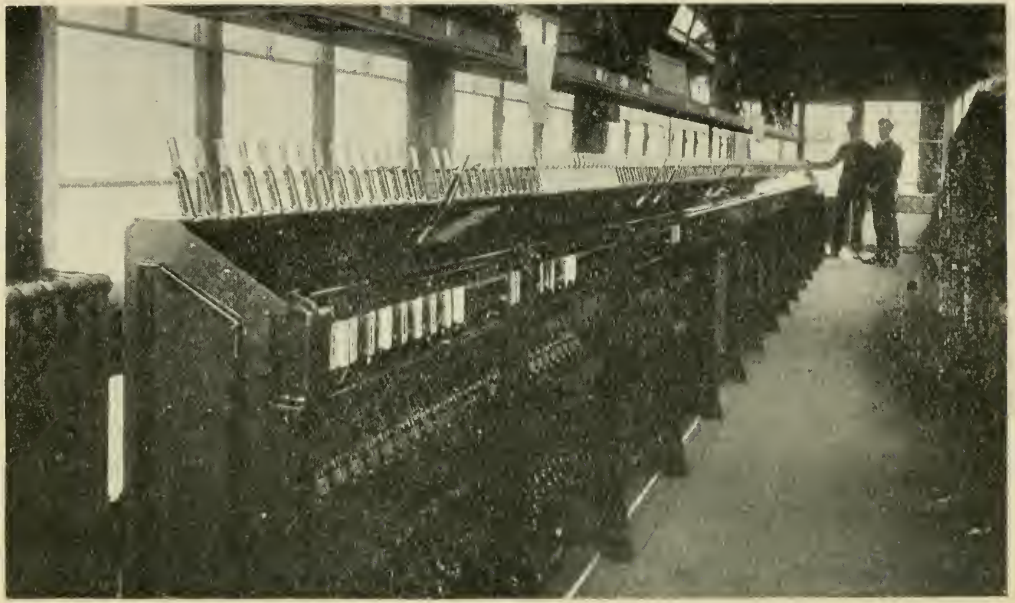


Fig. 18

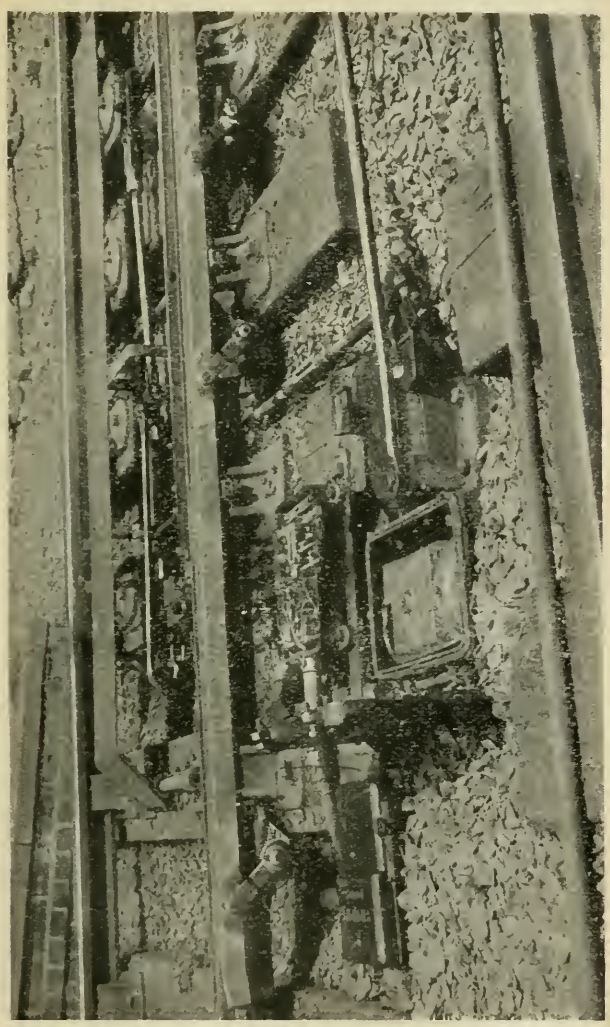


Fig. 19.

Fig. 20.

TRACK CIRCUITS AND AUTOMATIC SIGNALS.

D.C. TRACK CIRCUITS.

There is little doubt that the idea of the track circuit originated in England during the 'sixties, when Mr. W. R. Sykes installed an experimental track at the Crystal Palace Station. It was not, however, a success and nothing further was done in England for many years D.C. track circuits were introduced in America in 1879 and are now employed on a very large mileage. The first practical installation in this country was in 1901 on six miles of double line between Grateley and Andover on the L. & S.W. Railway. Since then progress has been continual.

Figs. 1 and 2 show simple track circuits. A double-rail track is more expensive than a single-rail, but is less liable to failure and should be installed whenever possible. In some cases, however, as noticed later, single-rail tracks only are permissible. The relay should be located at the entering end of the section. If at the leaving end, it will not release so quickly.

Relays and Batteries.—The pick-up and drop values of relays vary with different makes, but in no instance should the drop be less than 50 per cent. of the pick-up—60 per cent. is a better figure. With some makes it is higher than this, which is a great advantage The pick-up value should be kept low. Except under special circumstances, two grades of relay should only be used: 9w. and 4w. Whenever possible, the former should be employed, as a more sensitive shunt is obtained. With a ballast resistance of 3w. and less, the 4w. relay should be used; otherwise, the battery output is excessive. When adjusting a circuit, it is usual to allow a relay current of about 50 per cent. above the pick-up. In actual testing voltage readings should always be taken.

The gravity cell is used more largely for track purposes than any other primary cell. It has an E.M.F. of 1·079 and an internal resistance of about 1w. The best specific gravity is from 1,100 to 1,150. Two cells in multiple is the usual arrangement.

Accumulators are now largely employed. As a series resistance is introduced, the total resistance of the circuit can be adjusted to any desired point; the excessive current flow on short circuit obviated, and a better shunt obtained.

With good stone or gravel ballast, tracks a mile long are in successful operation. Cinder ballast is the worst.

Insulated Joints and Bonds.—Another type, much favoured owing to its cheapness, comprises an ordinary fish-plate with fibre between the rail and fish-plate.

Stranded copper bonds are preferable to ordinary iron wire bonds, as being of higher conductivity, but "Armco"

Iron Wire is now being adopted very largely for bonds, as its conductivity is very good, and its composition guaranteed at over 90% pure iron. Double bonding should always be employed.

A.C. TRACK CIRCUITS.

A.C. track circuits originated in America, being installed on the North Shore Railroad of California in 1903. Since then, they have been considerably developed and are largely employed on steam roads as well as electric roads. They were not employed in Great Britain until quite recently, when they were installed on portions of the London Underground Railways.

A.C. tracks are now standard for electric railways, owing to their immunity to foreign currents, whether A.C. or D.C. and regardless of their volume or direction. Figs. 8 and 9 are the simplest examples. In Fig. 10 the maximum track length is governed by the propulsion drop. Resistances are inserted to limit the propulsion current through the relay and transformer secondary, and a shunt impedance is often inserted across the relay. The maximum permissible D.C. voltage through the relay and transformer being known, the maximum track length can be determined. A track transformer with an open magnetic circuit is generally employed.

These restrictions do not apply to Figs. 11, 12 and 13, which are, therefore, well suited to heavy electric traction. Many 10,000 ft. end-fed and 2 ,0 0 ft. centre-fed double-rail tracks are in successful operation. The bond impedance being relatively constant and very low compared with the ballast resistance, changes in the latter have not much effect.

Transformers.—Either adjustable filler or constant potential track transformers can be used.

The adjustable filler type have a large and easily variable magnetic leak between the primary and secondary, so that they have a steep secondary voltage characteristic. The track leads of the secondary can, therefore, be connected directly to the track without a resistance or impedance in series.

Constant potential transformers are generally of the core type and require a resistance in series with track leads to limit the secondary short circuit current. On steam railways, and on double rail tracks on electric railways, it is more usual to employ an impedance with an iron core, which has a very low power factor. The short circuit current is, therefore, practically wattless. Either a resistance or impedance can be used with single-element track relays; with double-element relays the proper phase relations must be watched. Impedances must not be employed on single-rail tracks on electric railways, because the propulsion drop would saturate the iron core.

Another method is the employment of special non-inductive resistance termed "thermal regulators." Thus the increase in the secondary voltage, when the track is occupied, causes practically no increase in the secondary current, and the load on the transformer is, therefore, the same at all times; also, a much better shunt is obtained.

Relays.—A.C. track relays are of two classes—single-element, in which the power is received entirely from the track, and double-element, in which the power is received from the track and a local source.

Single-element.—The best of this class is the vane relay, which has an aluminium vane pivoted between the poles of an A.C. magnet. When the relay is energized, the vane is given an upward rotative movement and the contacts closed, because of the shifting magneto flux produced by shading bands on the upper halves of the pole faces.

The centrifugal relay consists of a squirrel-cage motor having a vertical shaft carrying centrifugal arms and collar, which lift and close the contacts. The stator winding being composed of two elements, the relay may be either a single-element or a double-element relay.

Double-element.—The ironless galvanometer relay has a moving coil pivoted inside a fixed field coil. As the torque tending to turn the armature and close the contacts is proportional to the produce of the flux in field and armature, the desired torque may be obtained through a very small current in the track element, and a comparatively large current in the local element, the two currents being closely in phase.

The polyphase relay, the most economical of all types, consists of an induction motor having a stator winding composed of two elements, in which the currents, of course, are in quadrature. Of the two, the current in the local element is by far the greater, so that very long tracks can be operated. When the rotor has revolved and closed the contacts, it stands still maintaining its torque.

The vane frequency relay has a double A.C. magnet, and a vane on each side of the spindle. By shading bands and adjustment of the magnetic leakages, no torque is produced on the vane by the 25-cycle propulsion current; only by the 60-cycle signalling current.

Double-element frequency relays must be of the centrifugal frequency type.

Single-element relays should only be used on short tracks. On long tracks their power consumption is excessive.

Impedance Bonds.—When both running rails are employed for the propulsion current return, impedance bonds must be introduced so that the propulsion current can freely pass from section to section, and yet the signalling current be confined to its own block.

The impedance bond consists of a laminated iron core provided with two heavy copper windings wound in opposite directions, and connected as shown in Fig. 14. The D.C. propulsion currents pass in opposite directions through the two halves of the winding, and produce no flux in the iron core. The A.C. signalling current, however, tends to flow through the two windings in series, and a high impedance results.

If the propulsion current in each winding is not equal, the unbalancing current will produce a flux in the iron core, and, therefore, a change in the bond impedance. Hence it is usual to increase the resistance of the iron core by an air-gap, which will, however, lower the impedance. A compromise must, therefore, be made, and bonds are usually designed to allow 20 per cent. unbalancing, without more than 6 per cent. change in impedance.

Bonds for A.C. propulsion employ the same principles, but are very much smaller than those for D.C. propulsion. As unbalancing troubles are rare, the air-gap in the core is generally omitted.

TRACK CIRCUITING THROUGH POINTS AND CROSSINGS.

On account of their relative simplicity and adaptability to adequate fouling protection and complicated layouts of switches and crossings, single rail track circuits are very largely employed at interlockings. If the continuous rail forms the propulsion current return, no appreciable return drop is experienced, owing to the shortness of the blocks.

As there are several methods of track circuiting a cross-over road and as these methods form the basis of more complicated schemes, it has been thought advisable to deal with them in some detail (Figs. 15-17).

Bonding should always be carried out on the series principle.

AUTOMATIC BLOCK SIGNALS.

GENERAL CONSIDERATIONS.

Automatic block signals with track circuit control were first installed in America in 1879, and by January 1st, 1914, the aggregate miles of road so protected were 26,123, the total miles of signal track being 87,185. The first installation in England was on the Liverpool Overhead Railway in 1893, the signals being controlled by electric contacts. The first track circuit controlled automatic block was on the L. & S.W. Railway, as previously mentioned.

Automatic signals are operated on the "normal danger" or "normal clear" system. Without detailing here the opinions as to the merits of each, it might be stated that the "normal danger" is employed in America only to a very small extent and in England only on the North-Eastern Railway. In the "normal clear" system, the circuit connections are fewer, and much simpler; it is cheaper to install and maintain, and failures are much less likely.

The principal signal mechanism is noticed later. In America all-electric signals are employed more extensively than all other types together, and the A.C. automatic block, apart from its usefulness on electric lines, is being largely installed on steam lines in preference to the D.C. block, the advantages being that it eliminates battery renewals; lamp cleaning and filling; troubles due to the exhaustion of, or damage to, the batteries by frost, and interference from foreign currents. It gives great economy in power cost, due to the efficiency of A.C. generation and transmission, and great economy in labour, because one man can maintain a greater mileage. Other advantages are the dependability and constant voltage of the A.C. power supply, and that much longer tracks can be operated without cut sections.

Mr. A. H. Rudd, Signal Engineer, Pennsylvania Railroad, stated recently* that although the cost of installation of A.C. automatic block was heavy, the operating and maintenance cost per mile per annum, on a four-track road, was 120 dollars (£24) cheaper than D.C. and 400 dollars (£80) cheaper than electro-pneumatic.

In England low-pressure pneumatic and electro-pneumatic signals have been installed to a much greater extent than electric. The signals themselves are simple, substantially constructed and work very well. Recently, however, some A.C. automatic block has been installed.

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* In an address before the Railway Club of Pittsburg, Pa., and published in the *Signal Engineer* (Chicago) for October, 1913.

Figs. 21 to 25 illustrate some typical arrangements

On the London Underground Railways, the length of the overlaps is about 400 ft., which is sufficient, although repeaters are not ordinarily provided, because train stops are employed. On most rapid transit lines, an automatic stop is located at each stop signal, and applies the continuous brake should a train pass a signal at danger.

In America, three-position automatic block signals operating in the right or left-hand upper quadrant are being largely installed. The great advantage of the three-position signal is that no distants are required. Compare Figs. 22 and 25.

On the Pennsylvania Railroad, stop signals are divided into two classes: "stop and proceed"; "stop and stay." Stop and proceed signals are the ordinary automatics, which are identified by the staggered lights (diagonal lights) and pointed-end arms as shown in Fig. 26. Stop and stay signals are interlocked signals, and have vertical lights and square or round-end arms. A driver can, therefore, pass a signal with a pointed-end arm at danger, but must stop until further instructions at a signal with a round or square-end arm.

The pointed-end arm is employed on many other American railroads for automatic signals.

In England, most of the automatic signals on the Metropolitan and Metropolitan District Railways are distinguished by having a white stripe down the centre of the arm. There is no distinction on other railways.

The practice of numbering automatic signals for identification purposes is most necessary, and almost universally employed.

ALL-ELECTRIC.

Semaphore Signals.—There are many types of electric signal machines. On the Metropolitan and East London Railways top-of-mast mechanisms are largely employed. This style of apparatus is considered superior to base-of-mast mechanisms as the necessity for connecting rods and levers is obviated.

The operation of the above-mentioned mechanism is typical of English practice. The motor operates the spectacle shaft through a train of gears and a slot mechanism. When the arm is cleared the motor is cut out and the signal held "off" by the current in the slot magnet. On the latter being de-energized the arm returns to danger without driving the motor and gearing, under the control of a dashpot.

10, 20 and 60-volt series wound motors are employed for D.C. mechanisms. In A.C. mechanisms, series wound commutating and induction motors are both employed, but present practice favours the induction motor, as it is the simplest, having few wearing parts, and no commutator or brushes. Although it requires more current

than the series motor, the additional cost is counterbalanced by lower maintenance cost and greater reliability. The slot magnets are of the tractive type with shading bands.

In America, the base-of-mast style of mechanism is contained in a large iron box forming the base of the post, so that the signal can work in any weather The operation is much the same as described above.

In the top-of-mast mechanisms usually employed the operation is entirely different from those in England A typical feature is the elimination of slot and dashpot, the motor being directly connected to the spectacle shaft by a train of gears.

10, 20 and 110-volts series motors are employed in D.C. mechanisms. In the first two the arm is held at "caution" and "clear" by a retaining device; while in the last, the motor armature constitutes the means for holding the signal. Two of the pole pieces have serrated surfaces, so that when certain holding field windings are energized, the attraction between armature and pole pieces prevents the rotation of the armature. In these mechanisms the arm, when returning to stop, drives the motor backwards, so that it acts as a generator, discharging current through a resistance, and producing a frictionless dynamic brake.

In A.C. mechanisms, an induction holding device is employed, the rotor being loosely mounted on the motor armature shaft. When the arm is at "caution" or "clear" the stator windings of the device are energized and the attraction between the poles of the rotor and stator prevents the rotation of the armature shaft. A spring stop is used to check the momentum of the arm when returning to the stop position.

Light Signals.—These are largely employed on the London Underground Railways, and in America on trolley lines, and in tunnels and terminals. The light signal, having no moving parts, is not subject to failure through weather conditions; small space is required and maintenance costs are very low. One type consists of an iron case containing one red and one green Fresnal lens, behind each of which is placed one, or sometimes two, incandescent lamps, the indications being controlled by a relay.

Fig. 22 shows the operation of some A.C. light signals, in which the use of relays is avoided and any chance of false indications from wire crosses prevented. When the green light circuit is open, the high impedance of S^1 allows the red lamps to light up. Immediately the relay closes the green light circuit the magneto motive forces of S^1 and S^2 are equal and opposite, so that no flux is produced in the iron core. The impedance of S^1 being then very slow, the red lamps are short circuited.

Light signals fixed in the open are provided with hoods to keep away the sunlight and ensure an efficient indication.

ELECTRO-PNEUMATIC.

In the ordinary style of mechanism air at a pressure of about 70 lbs. per square inch is admitted into a cylinder under the control of an electro-magnetic valve, the piston of the cylinder being connected to the signal arm through a counterweight lever and upright rod. The cylinder is 3 in. bore by 4 in. stroke.

On the Metropolitan District Railway, the arm spindle lamp bracket and E.P. motor are all carried by one casting. The cylinder is movable and connected to the arm, the piston being stationary, so that the air pressure forces up the cylinder and moves the arm into the " off " position against the downward pressure of a heavy spectacle

LOW-PRESSURE PNEUMATIC.

These signals are installed on six miles of double line between Grateley and Andover on the L. & S.W. Railway. They are of the piston-operated type, with air at 15 lbs. per square inch under the control of electro-magnetic valves. Round iron posts are employed and the operating mechanism is contained in a large cast-iron box forming the base of the post.

Later, the 24 miles of four-track road between Basingstoke and Woking were equipped. These signals are diaphragm operated and are fixed on bridges spanning the lines. The simplicity of the mechanism and absence of friction in its moving parts have made this signal extremely successful in working.

Those desiring to pursue the subject further should consult :—

" Power Railway Signalling," by H. Raynar Wilson.
" The Signal Dictionary "
" Automatic Block Signals and Signal Circuits," by Ralph Scott.
" The Signal Engineer," published monthly.
Annual Proceedings of the " Railway Signal Association," and the " Institution of Railway Signal Engineers."

TYER'S PATENT SIMPLE ELECTRIC MOTOR FOR SIGNALS.

The Motor is shown in Figures 1, 2 and 3. It consists of :—

An Electric Motor A (Fig. 3), on the axle of which are fixed—
A Pulley with two grooves B, and
A tempered Steel Disc C.

In the two grooves of the pulley B are wound in opposite directions, and several times over themselves, the ends of a metal band D which passes over a pulley E (Figs. 2 and 3). The frame of the pulley E is connected by a wire rope to the signal arm to be operated. When the signal arm is at danger the radius of the coiled band is the same in the two grooves of the pulley E.

In proximity to the disc C (Fig. 1) is mounted a lever F to the extremity of which is fixed the armature G of an Electro-magnet H.

To the lever F is also fixed a tempered steel plate I ; a tempered steel roller J is wedged between the plate I and the disc C when the lever F is held by the electro-magnet H. The disc C and the axle to which it is fixed cannot under these conditions turn in an anti-clockwise direction.

When the lever F is no longer held by the electro-magnet H, the roller falls by its own weight on to the stop K (Fig. 1). The movement of the axle then becomes entirely free.

The rectangular metal tube S is for the purpose of protecting the pulley E and the metal band D.

METHOD OF WORKING.

When the circuits of the motor A (Fig. 3) and the electro-magnet H (Figs. 1 and 2) are closed, the pulley B (Fig. 3) and the disc C are turned in a clockwise direction, the roller J (Fig. 1) being meanwhile supported over the disc C by the lever F, which is attracted by the electro-magnet H.

During the rotation the diameter of the coiled band D (Fig. 3) is increased in one of the grooves of the pulley B, and decreased in the other groove. The pulley E is thereby raised as in a differential pulley gear. Owing to the diameter of the coiled bands being equal at the moment of starting, the revolving axle is enabled quickly to pick up speed.

The differential action increases gradually until the signal arm has been lowered, when the circuit of the motor A is automatically broken.

When the pulley E has stopped rotating the roller J (Fig. 1) falls and is wedged between the disc C and the plate I, and the lever F being attracted by the electro-magnet H, the circuit of the motor A being broken, the

motor is stopped. The counterweight of the signal arm, which tends to return the arm to the danger position acting on the strap of the pulley, creates a slight movement of the shaft P in an anti-clockwise direction. This reverse motion of the shaft P is instantly stopped by the roller J, which wedges between the disc C and the steel plate I.

In order to allow the signal arm to go to danger, all that is necessary is to break the circuit of the electro-magnet H which liberates the armature G. The lever F, which is no longer held, allows the roller J to fall on to the stop K, and the shaft P, moving in an anti-clockwise direction, places the signal arm to danger. The signal arm is placed to danger very gently, yet sufficiently rapidly, owing to the movement being quickest at the moment when the release takes place. The Signal Motor requires very little current, and is satisfactorily operated, even when used very frequently by two sets of 6 Sac Leclanché Cells in parrallel, the time taken to lower the signal arm being about 3½ seconds

The motor, of course, may be operated by either batteries, as stated, or from "Main" supplies.

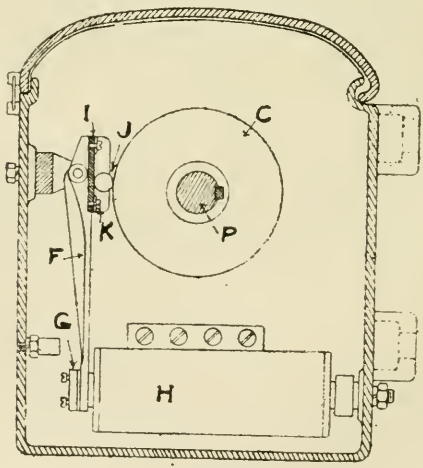


Fig. 1.

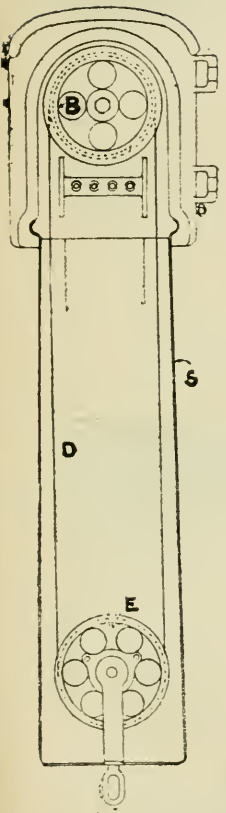


Fig. 2

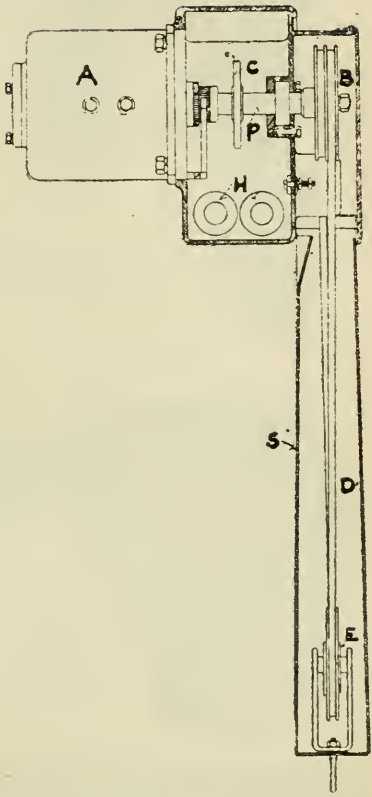
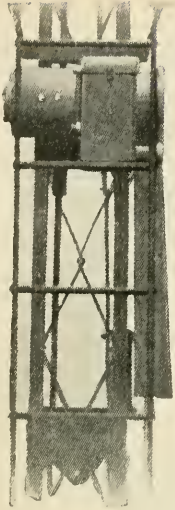
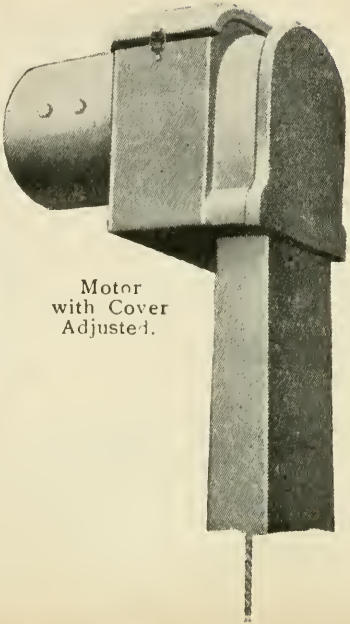


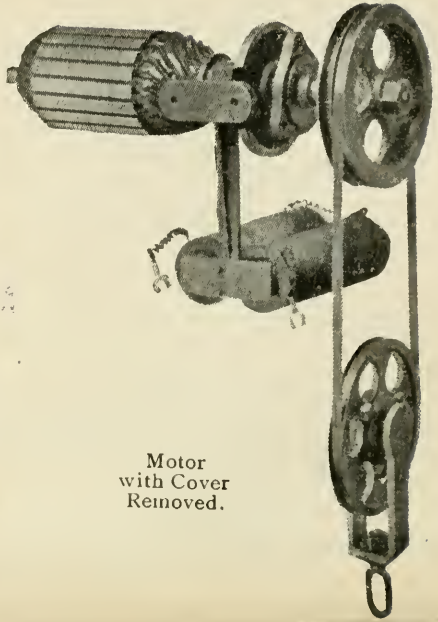
Fig. 3



End View showing position of Motor on Signal-post.



Motor with Cover Adjusted.



Motor with Cover Removed.

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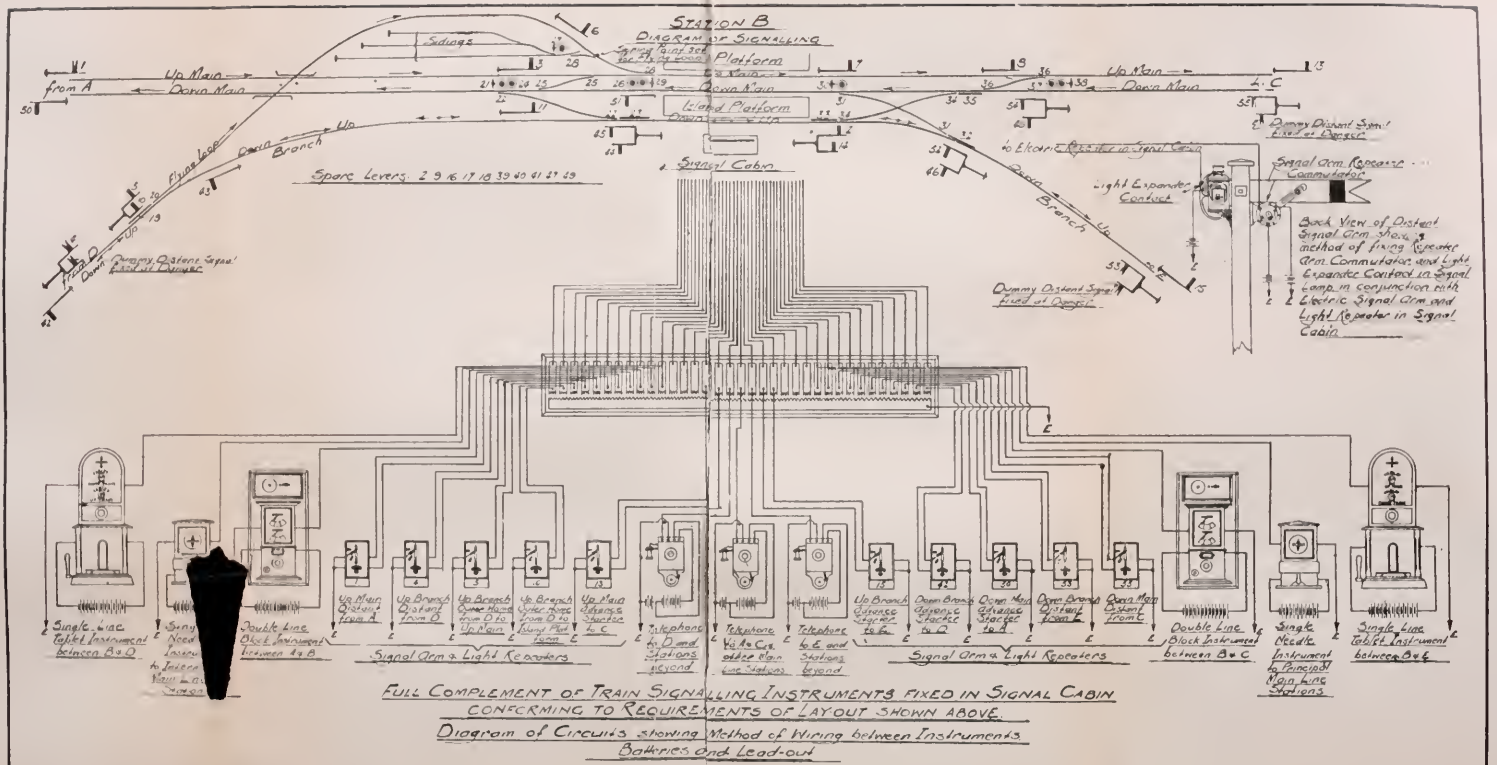

STATION B
DIAGRAM OF SIGNALLING
Platform
Island Platform
Up Main
Down Main
Up Loop
Down Loop
Up Branch
Down Branch
Sidings
Spare Levers 2 9 16 17 18 39 40 41 47 49
Signal Cabin
Dummy Distant Signal fixed at Danger
Electric Signal Arm in Signal Cabin
Light Expander Contact
Signal Arm Repeater Commutator
Back View of Distant Signal Arm showing method of fixing Repeater Arm Commutator and Light Expander Contact in Signal Lamp in conjunction with Electric Signal Arm and Light Repeater in Signal Cabin
Single Line Tablet Instrument between B & D
Double Line Block Instrument between B & D
Up Main Distant from A
Up Branch Distant from B
Up Branch Outer Home from D to Up Main
Up Branch Outer Home from D to Island Plat. Home & C
Up Main Advance & Starter to C
Telephone to D and Stations Beyond
Telephone to A & Cabs. at the Main Line Stations
Telephone to E and Stations Beyond
Up Branch Advance Starter to E
Down Branch Advance Starter to A
Down Main Advance Starter to A
Down Branch Distant from E
Down Main Distant from C
Signal Arm & Light Repeaters
Double Line Block Instrument between B & C
Single Needle Instrument to Principal Main Line Stations
Single Line Tablet Instrument between B & E

FULL COMPLEMENT OF TRAIN SIGNALLING INSTRUMENTS FIXED IN SIGNAL CABIN CONFORMING TO REQUIREMENTS OF LAY-OUT SHOWN ABOVE.

Diagram of Circuits showing Method of Wiring between Instruments Batteries and Lead-out

To face page 101.

D.C. Track Circuit
Single Rail Type

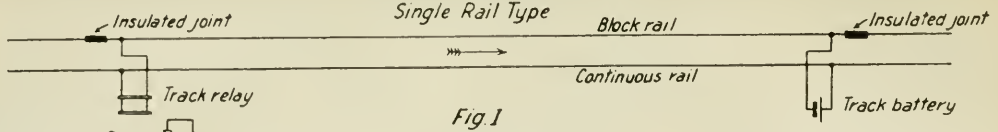


Fig. 1

This type will not detect broken rails if occurring in the continuous rail.

D C. Track Circuit
Double Rail Type

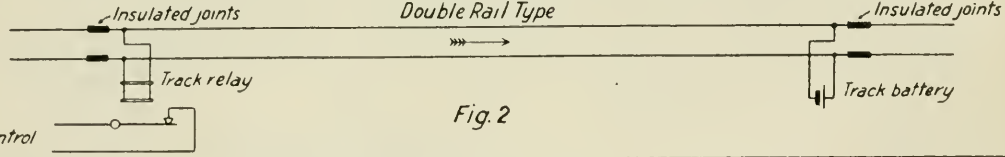


Fig. 2

Cut Section Track Circuit

A single section divided in the middle owing to difficulty in operating a long track

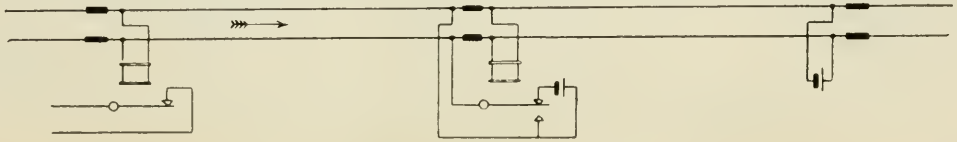


Fig 3

D.C. Track Circuits fed from power supply

Installed on some of the London Underground Electric Railways

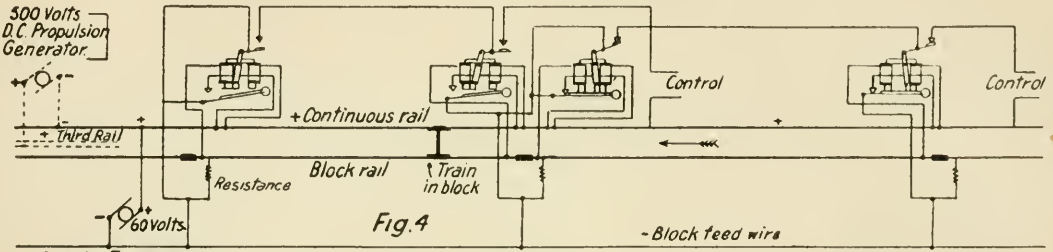


Fig. 4

On Boston Elevated Railroad, the continuous rail forms the propulsion current return (connections shewn dotted), with the return rail bonded to the elevated structure & short blocks, the return drop is very small

Track Circuit arrangements for protecting trains standing at starting signals

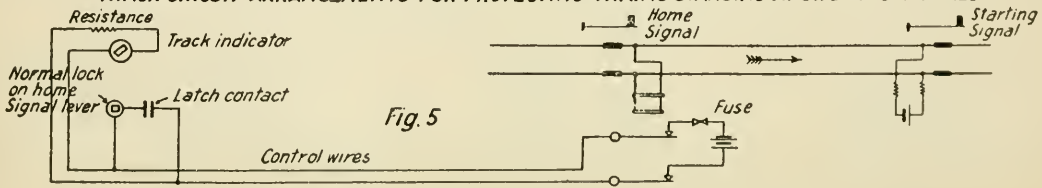


Fig. 5

When track in rear of starting signal is occupied, lock on home signal cannot be released

TRACK CIRCUIT ARRANGEMENTS FOR PROTECTING TRAINS STANDING AT HOME SIGNALS.

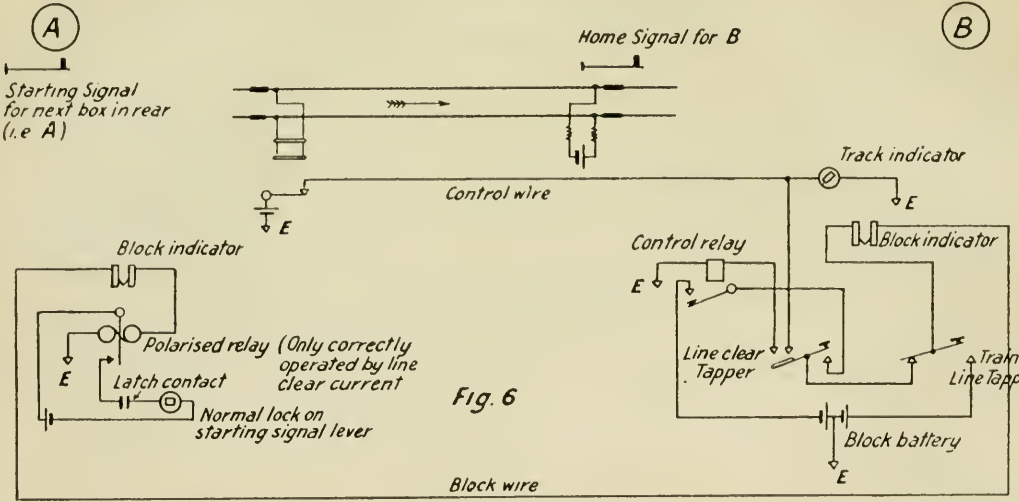


Fig. 6

Lock on starting signal at A can only be released when line clear is sent by B, which cannot be given if track in rear of home signal at B is occupied.

TRACK CIRCUIT ARRANGEMENTS FOR PROTECTING TRAINS OCCUPYING PLATFORM ROADS

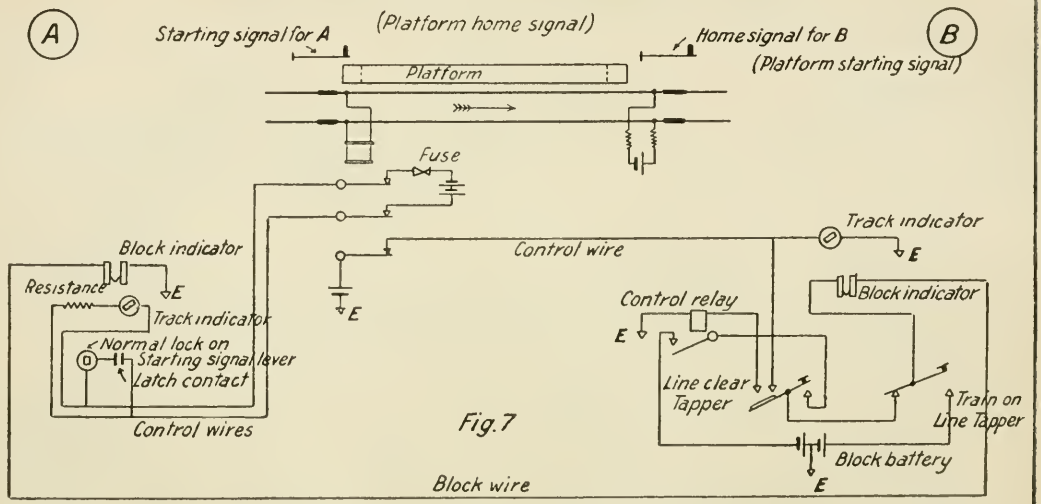
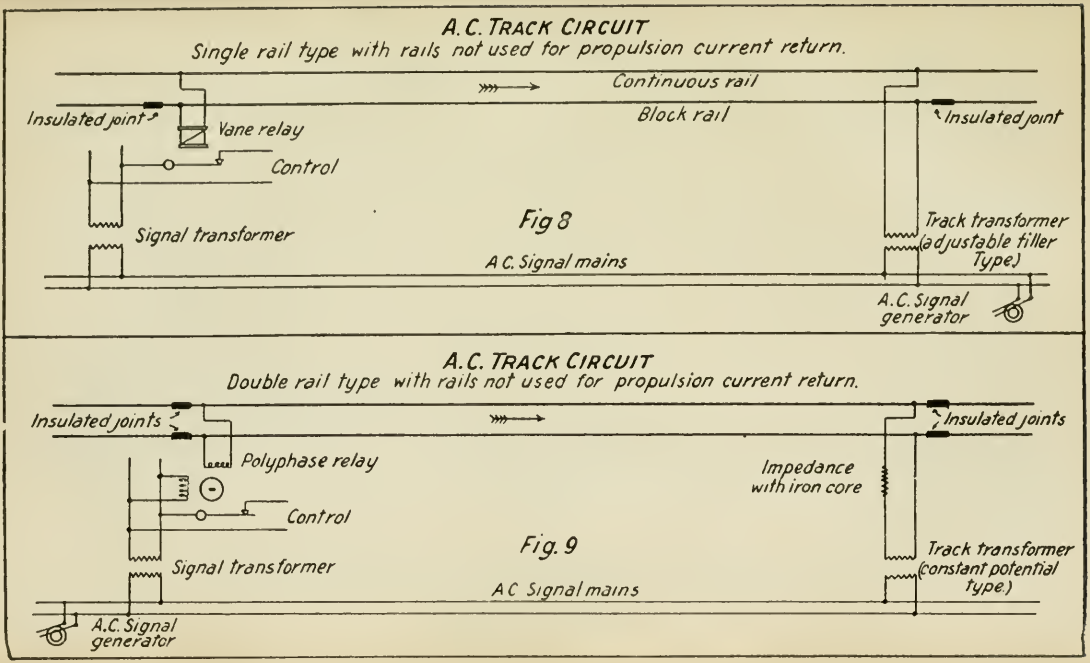


Fig. 7

Lock on starting signal for A cannot be released or line clear given by B when track is occupied.
A track indicator is provided in both boxes


A.C. TRACK CIRCUIT
Single rail type with rails not used for propulsion current return.
Continuous rail
Block rail
Insulated joint
Vane relay
Insulated joint
Control
Signal transformer
Fig 8
Track transformer (adjustable filler Type)
A.C. Signal mains
A.C. Signal generator
A.C. TRACK CIRCUIT
Double rail type with rails not used for propulsion current return.
Insulated joints
Insulated joints
Polyphase relay
Impedance with iron core
Control
Fig. 9
Track transformer (constant potential type.)
Signal transformer
A.C Signal mains
A.C. Signal generator

A.C. Track Circuit.

Single rail type with continuous rail used for D.C Propulsion current return

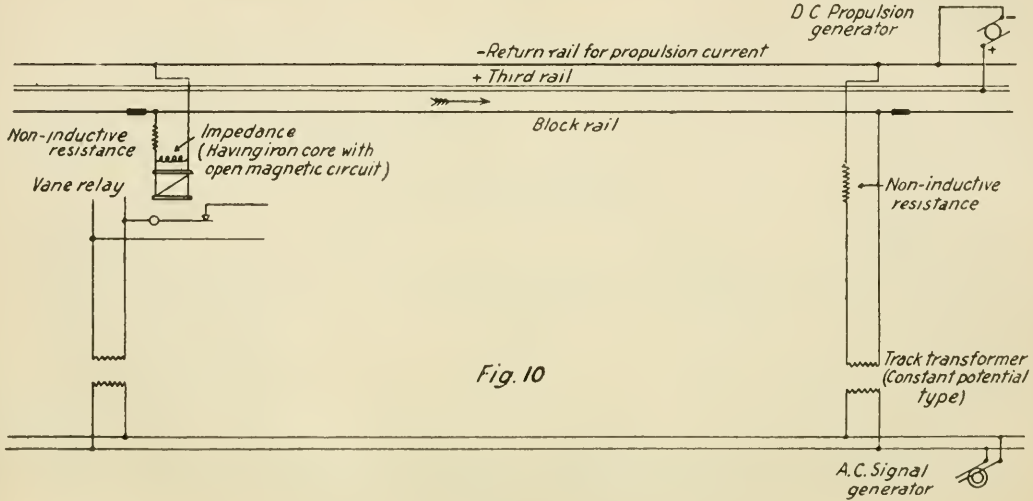


Fig. 10

A.C. Track Circuit.

Double rail type with both rails used for D.C. Propulsion current return

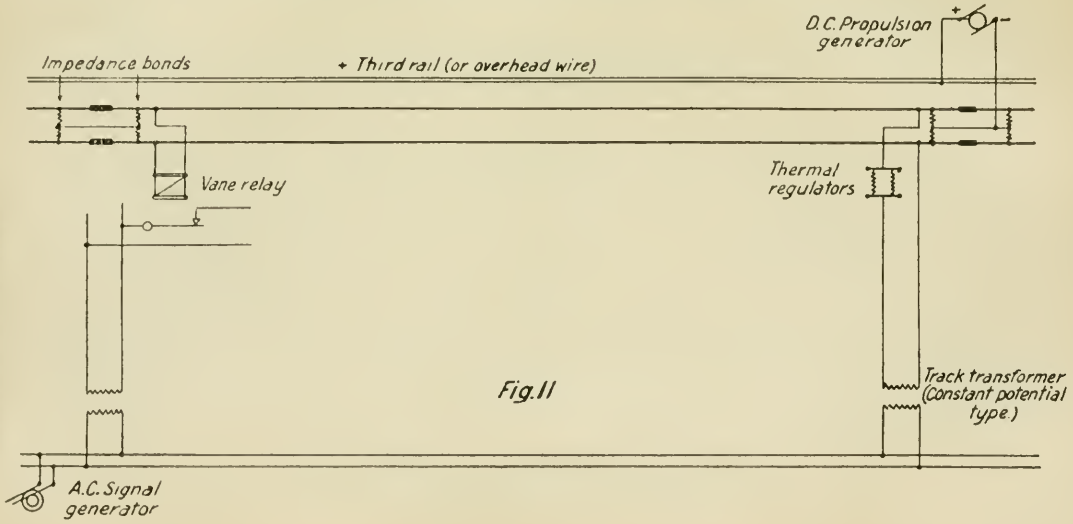
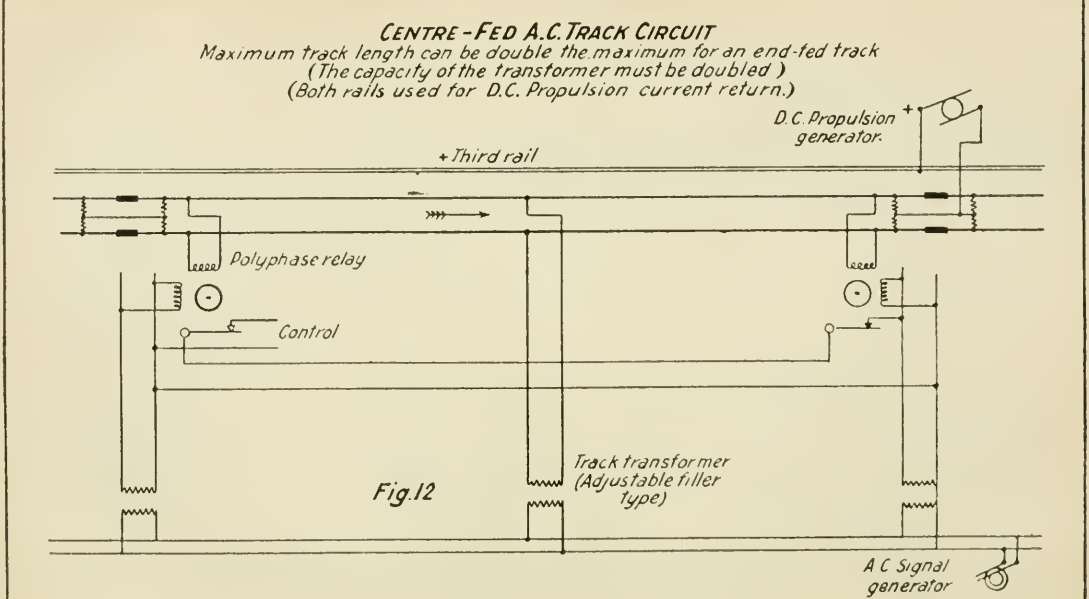


Fig. 11


CENTRE-FED A.C. TRACK CIRCUIT
Maximum track length can be double the maximum for an end-fed track
(The capacity of the transformer must be doubled)
(Both rails used for D.C. Propulsion current return.)
D.C. Propulsion generator
+
+ Third rail
Polyphase relay
Control
Track transformer (Adjustable filler type)
A.C. Signal generator
Fig. 12

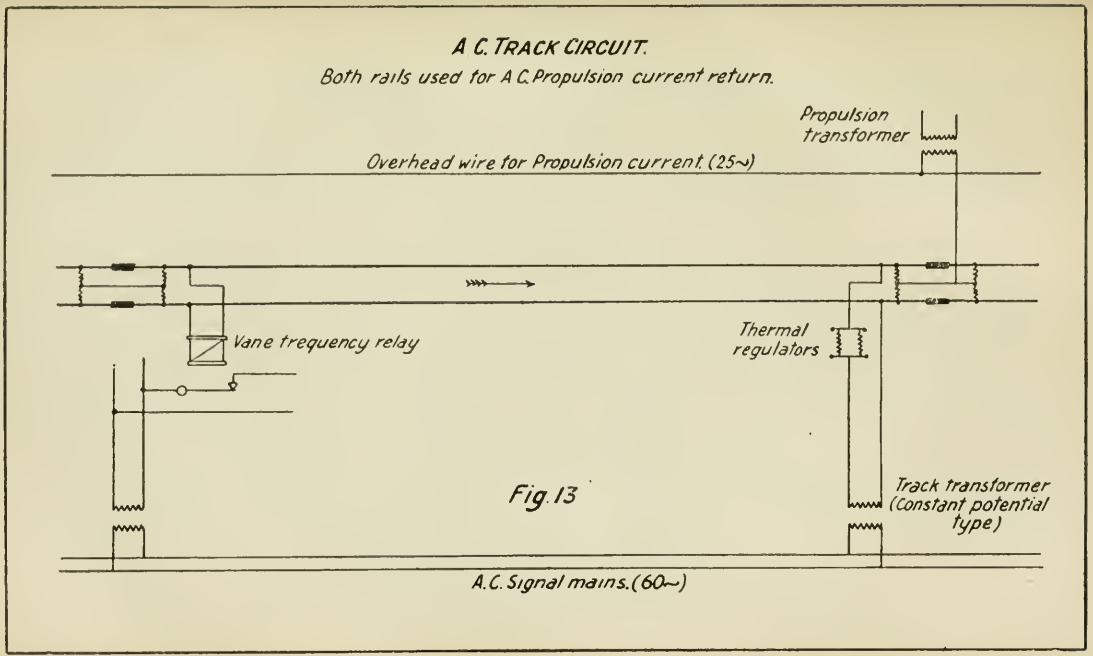

A C. TRACK CIRCUIT.
Both rails used for A C. Propulsion current return.
Propulsion transformer
Overhead wire for Propulsion current. (25~)
Vane frequency relay
Thermal regulators
Track transformer (Constant potential type)
A.C. Signal mains. (60~)

Fig. 13

ARRANGEMENTS OF IMPEDANCE BONDS FOR DOUBLE-RAIL TRACK CIRCUIT WITH D.C(OR A.C) PROPULSION CURRENT IN RUNNING RAILS

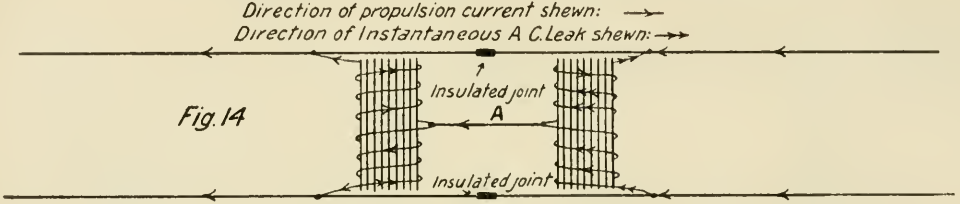


Fig. 14

"A" is called the "Neutral Connection" & is a heavy cable connected across the neutral points of the bonds to carry the propulsion current from one track circuit to the other

PROTECTION FOR MAIN LINE CROSSOVER.

Single Rail Tracks
Great Western Railway.

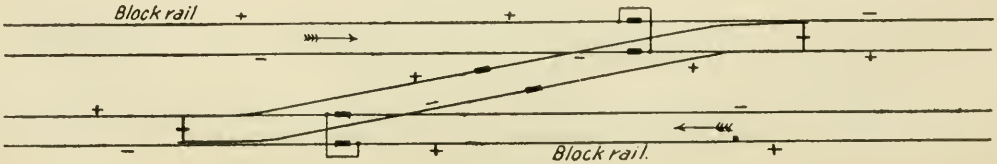


Fig. 15

PROTECTION FOR MAIN LINE CROSSOVER.

Single Rail Tracks

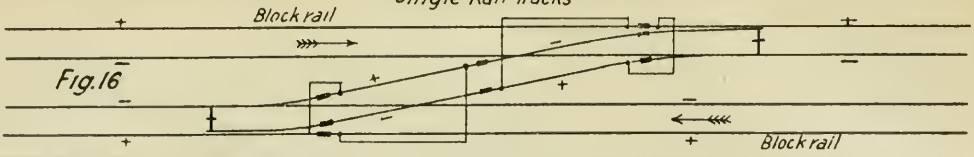


Fig.16

PROTECTION FOR MAIN LINE CROSSOVER

Single Rail Tracks

Employed on some of the London Underground Electric Railways

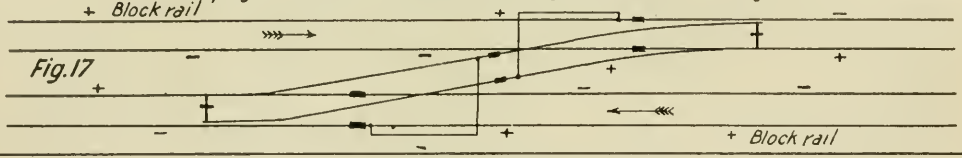


Fig.17

TRACK CIRCUITING A DIAMOND CROSSING.

Single Rail Tracks

Employed on some of the London Underground Electric Railways

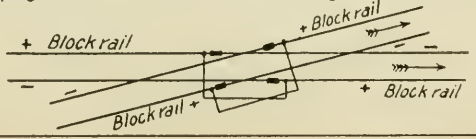


Fig.18

TRACK CIRCUITING A DOUBLE COMPOUND.

Single Rail Tracks.
Employed on some of the London Underground Railways

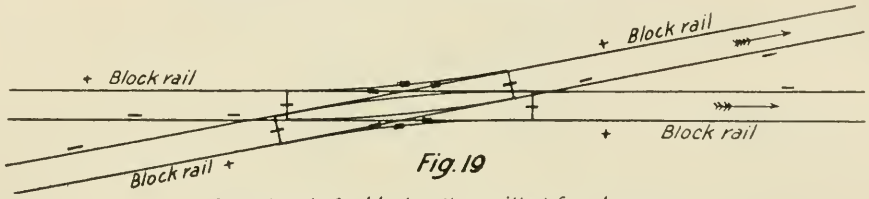


Fig. 19

Cross bonds for block rails omitted for clearness.
They are connected on the method shown in fig. 18

PROTECTION FOR SIDING CROSSOVER

Single Rail Tracks

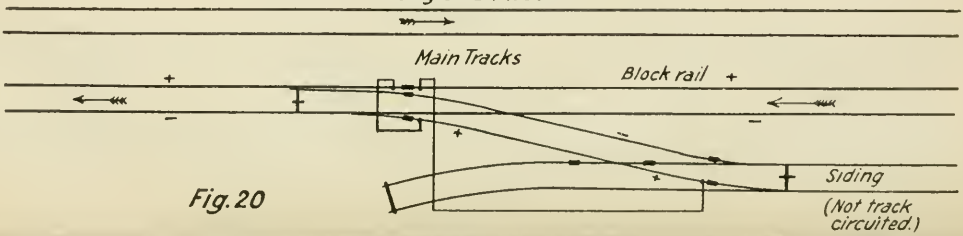
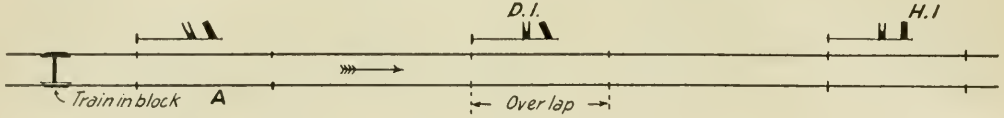


Fig. 20

NORMAL DANGER AUTOMATIC BLOCK SIGNALS.

With overlaps 400 yards long
North Eastern Railway Aine to Thirsk

Fig. 21

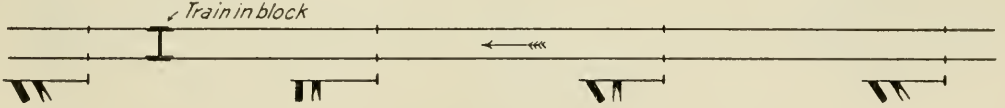


Electro-gas signals controlled by D.C. tracks with blocks 1030-1270 yards long
When train enters overlap A, signals H.I. & D.I. will clear provided controlling tracks ahead are unoccupied.

NORMAL CLEAR AUTOMATIC BLOCK SIGNALS

Without overlaps
London & South Western Railway Grateley to Andover

Fig. 22

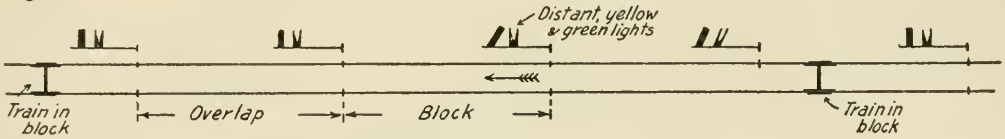


Low-pressure pneumatic signals controlled by D C tracks with blocks a mile long

NORMAL CLEAR AUTOMATIC BLOCK SIGNALS

With overlaps.

Fig.23 Interborough Rapid Transit Company's Subway Division. New York.

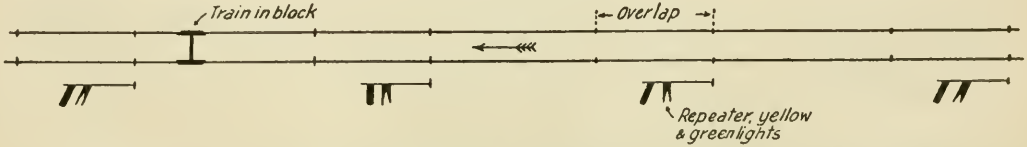


Electro-pneumatic signals controlled by A.C. tracks
The overlap equals the block length, which is as short as possible, the average being 820. ft.
This distance equals full speed braking distance plus 50%

A.C. AUTOMATIC BLOCK SIGNALS

Two-position upper quadrant with 400-700. feet overlaps.
Metropolitan Railway. Wembley Park to Harrow

Fig. 24

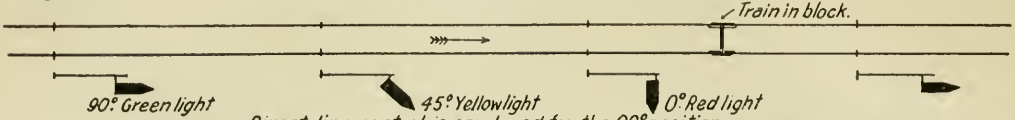


The overlaps are separate tracks, so that a signal is replaced to danger immediately after being passed

A.C. AUTOMATIC BLOCK SIGNALS.

Three-position upper quadrant without overlaps.
New York Central & Hudson River Railroad. Electric Zone

Fig.25



Direct line control is employed for the 90° position.

STANDARD ASPECTS OF AUTOMATIC SIGNALS.

Pennsylvania Railroad.

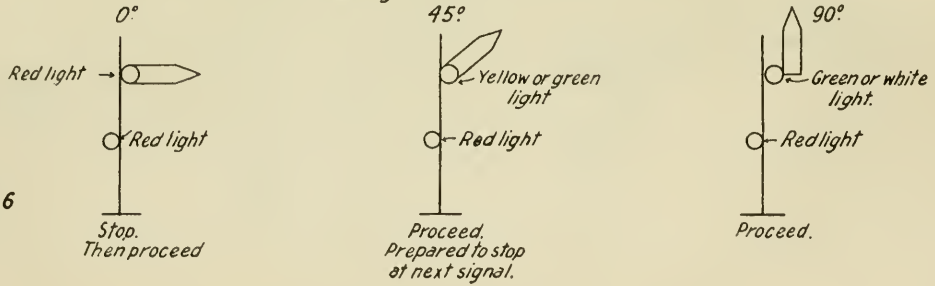
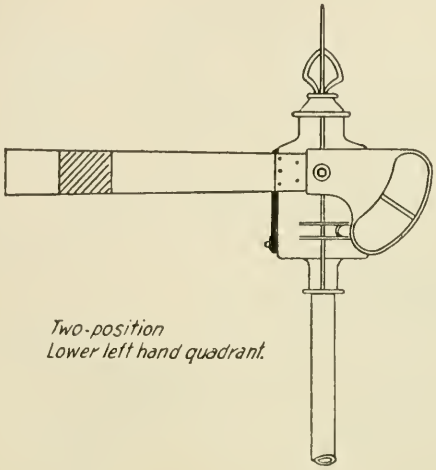


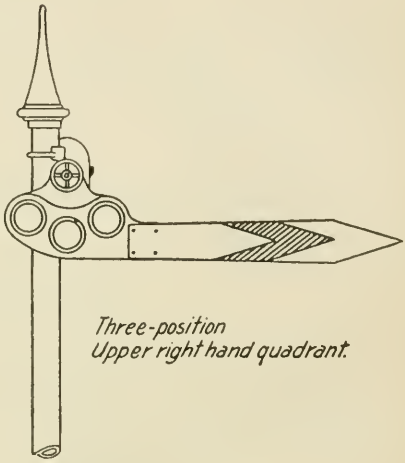
Fig.26

Signals fitted with staggered marker lights.

TYPES OF ELECTRIC TOP OF MAST SIGNAL MECHANISMS.



Two-position
Lower left hand quadrant.



Three-position
Upper right hand quadrant.

Fig. 27

This figure shows clearly the advantages of the upper quadrant mechanism.

CIRCUIT DIAGRAM.

Two-position D.C. Automatic signal with 10 volt motor

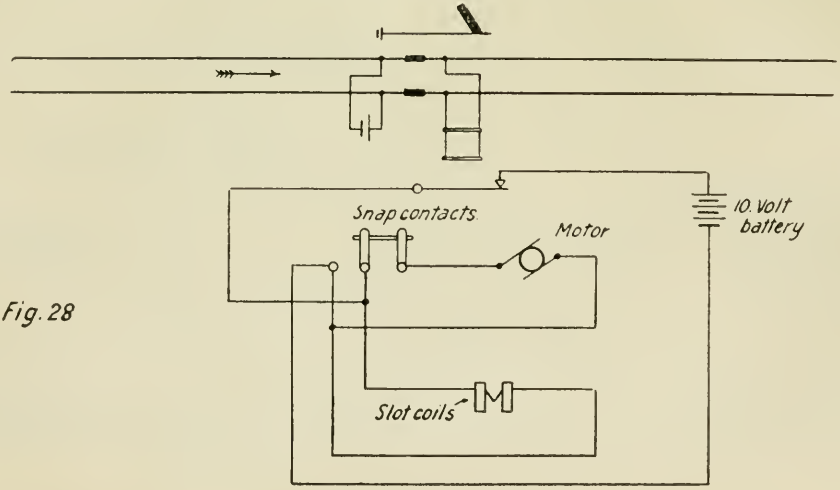


Fig. 28

(English Practice.)

CIRCUIT DIAGRAM.

Three-position D.C. Automatic signal with 10. volt motor

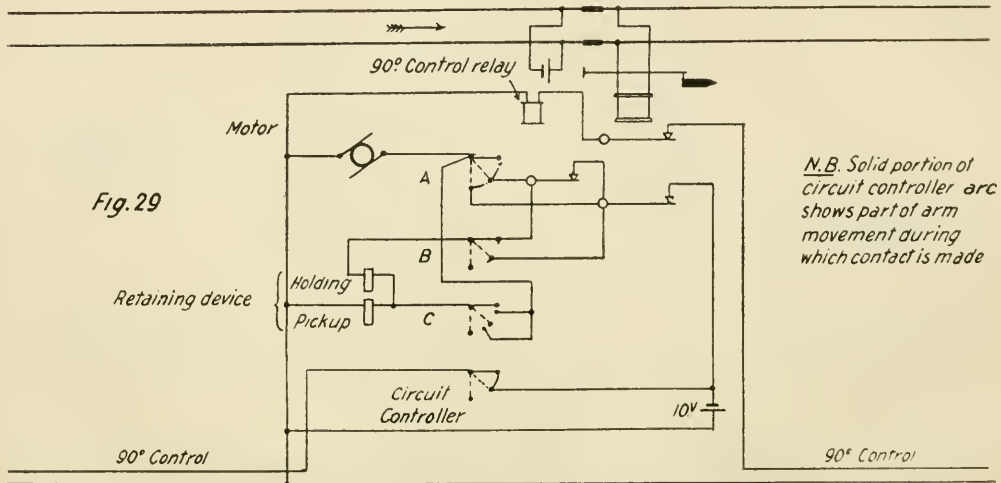


Fig. 29

N.B. Solid portion of circuit controller arc shows part of arm movement during which contact is made

CIRCUIT DIAGRAM.

Three-position A.C. Automatic signal with induction motor.

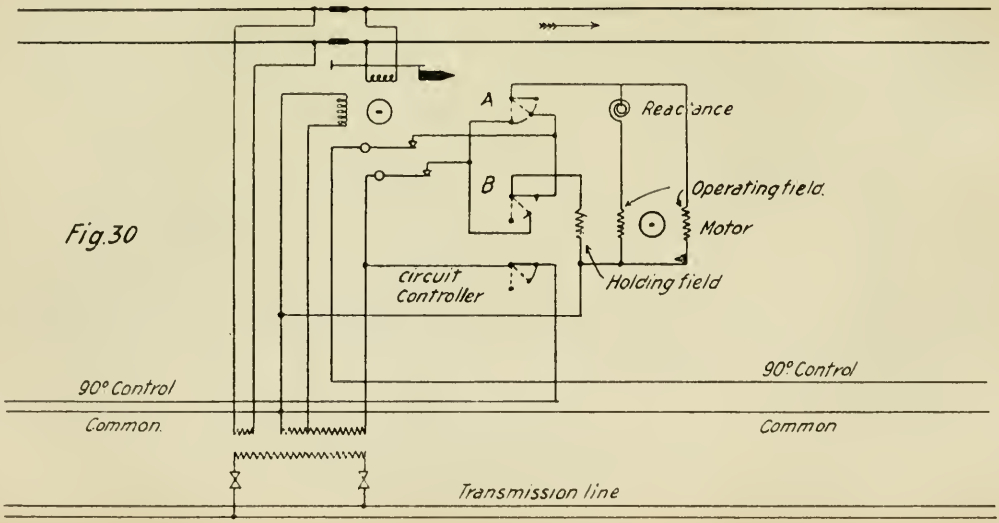


Fig.30

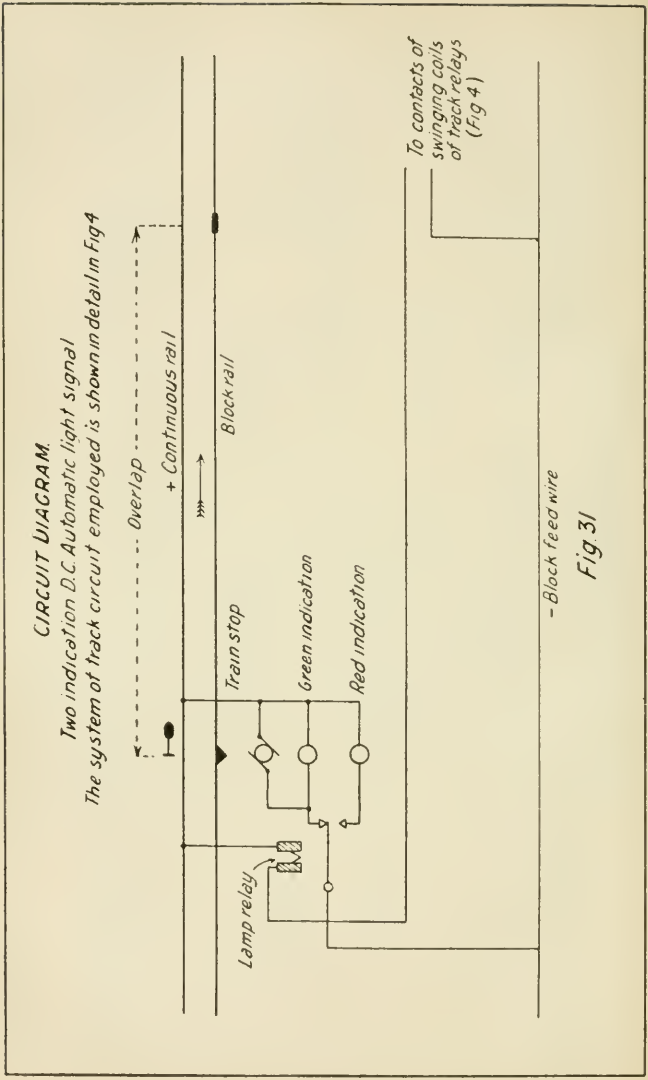
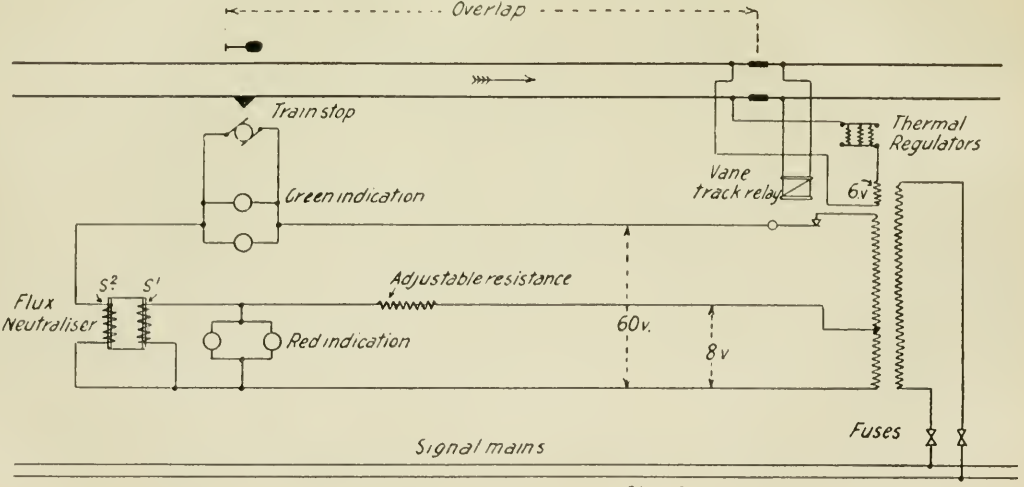

CIRCUIT DIAGRAM
Two indication D.C. Automatic light signal
The system of track circuit employed is shown in detail in Fig 4
Overlap
+ Continuous rail
Block rail
Train stop
Green indication
Red indication
Lamp relay
To contacts of swinging coils of track relays (Fig 4)
- Block feed wire

Fig. 31

CIRCUIT DIAGRAM

Two-indication A.C. Automatic light signal.

Fig.32 Installed on some of the London Underground Electric Railways



Adjustable resistance enables ampere-turns in S¹ & S² to be made equal.

ARRANGEMENT OF ELECTRICAL SIGNALLING INSTRUMENTS IN SIGNAL CABIN.

Amongst the appliances adopted on Railways to safely negotiate traffic from point to point, electrical train signalling Instruments probably rank foremost.

The number and type of instruments to be installed depend upon the lay-out, and the specific traffic conditions applicable to the installation within the control of the signal cabin.

On account of the limitation of space, Double Line Permissive Block Instruments have not been shown on the accompanying diagram. These instruments have been introduced for the purpose of indicating at each end of the section the number of trains in the section when permissive working is in operation.

The diagram shows clearly the full complement of electrical instruments as fixed in the signal cabin properly wired up in order to fulfil the requirements of the lay-out.

It will be noticed that this installation comprises a double main line with two single branch lines, including a flying junction.

This installation necessitates the undermentioned electrical apparatus :—

2 Single-Line Tablet Instruments.
2 Single-Needle Telegraph Instruments.
2 One-wire Three-Indication Block Instruments.
3 Telephones.
10 Signal Arm and Light Repeaters for repeating electrically the respective Distant and Outer Home Signals to which they are applicable.

In the diagram there is also shown the back view of an outside fixed signal illustrating the method of fixing the Repeater Arm Commutator and the Light Expander for repeating the Light Indicator in the signal box. The wiring is shown from the instruments to the batteries and to the lead-out, and the various circuits can be readily traced.

It does not often occur that complete sets of both double and single-line instruments are incorporated in one cabin, the present scheme shown being rather special on account of the peculiarity of the lay-out.

The example, however, is a good one to illustrate a complete number of instruments grouped together to govern an installation worked by, and under the jurisdiction of, one or more signalmen in one cabin.

THE BLOCK SYSTEM.

BLOCK INSTRUMENTS.

Block instruments are of two general classes, " One-wire " and " Three-wire." In the former, the bell signals and block indications for both up and down lines pass over the same wire, whilst in the latter, a separate wire is provided for the up signals, the down signals and the bell. Both classes are in extensive use.

In the " One-wire " system, the saving of cost in the running of block wires is clearly very considerable.

" Three-position " and " Two-position " blocks are both employed, but the latter now only to a limited extent. In the "three-position " the indications are " Line blocked " (the normal position of the block indicator) " Line clear " and " Train on line " ; in the two-position " Line clear " and " Train on line " only.

A popular form of three-position block instrument is the single needle, which is generally similar in construction to the railway type of single needle telegraph instrument, separate instruments being provided for the up and down lines and three-line wires. The needle is adjusted and balanced, so that in its normal postion it is vertical and in the centre of the dial, thereby indicating " Line blocked." The London and North-Western Railway type of single-needle instrument is of the combined type, and the bell is fixed in the base.

Figs. 1 and 2 show Tyer's patent one-wire three-indication block instrument, which is in extensive use in all parts of the world. Some of the special features of this instrument are :—

Interlocking of commutator with the plunger. This is so arranged that when the commutator is turned from any one position to another no further movement can take place until the plunger is pressed home and the signal recorded, when the commutator is again free. All these turning movements are in one direction and the commutator being nicely balanced, all signalling operations are easily manipulated with one hand.

A small plunger is fitted below the boss of the commutator, which operates a stop lever or detent ; this plunger requires to be momentarily depressed in order to free the commutator when the latter is turned, as the detent forms the banking stop for each movement.

The dial movements are of the well-known Cylinder armature pattern, and mounted on the dial plate and in close proximity to each movement is a small local locking coil, having at the extreme end of its armature a small cam escapement, this cam being so arranged that it allows of a free traverse of the Cylinder Armature and needle in one direction, but checks the reverse movement and holds the needle when half the distance has been completed ; of

these locking coils the lower one, which engages with the armature of the needle recording "outgoing" currents, is operated by the commutator and local battery; the upper locking coil, engaging with the armature of the needle recording "received" currents is operated by a special relay in the line circuit, and which is fitted in the bell case. The action of the relay is such that in responding to currents of full strength, *viz.*: ("Line Clear" and "Train on Line") it attracts the armature the full distance and closes the bell circuit direct; but to currents of fractional value, *viz.*: ("Line Blocked") it attracts the armature to a movable contact arm only, this putting the upper local locking coil in the bell circuit.

In the normal position of the instrument the needles show "Line Blocked" ("Train out of Section" or "Line Closed"), and the first commutation from this position sends a current of full strength to the line; this causes the needles to traverse the full distance and show "Line Clear," at the same time operating the armature of line relay fully which simply closes the bell circuit.

The next commutation sends a reverse current of full strength to line, which also operates the armature relay fully, but does not allow of a complete traverse of the needle in the reverse direction, owing to the cam of small locking coil checking the cylinder and allowing the needle to occupy a central position showing "Train on Line."

The third and final movement of the commutator splits the current, short circuiting three-fourths of it through the lower locking coil and operating the armature, allowing the needle recording "outgoing" currents to show "Line Blocked"; at the same time the remaining current of one-fourth the full strength is sent to line, this current being too weak to operate the armature the full distance, attracts it to the movable arm; this, in addition to closing the bell circuit, operates the upper locking coil, the armature of which engages with the cylinder of the "receiving" needle, is lifted, the needle is freed, thus allowing it to traverse the remaining distance and show "Line Blocked."

Only one battery is required for each instrument, and there are no permanent currents flowing, the whole of the signalling being accomplished by momentary currents.

This instrument can be readily adapted to all signal interlocking, such as level crossing gates, starting signals, distant signals, out of view of either cabin, etc., and can at any future time be fitted with the additions required for "Lock and Block" working at a small additional cost.

Where foreign currents are experienced, a metallic return is usually employed, and it is good practice where three-wire block instruments are in use to have one common for the dials and another for the bells. 400 lb. galvanized iron wire, having a resistance of 1·332 ohms per mile, is usually employed for the line, and 800 lb. wire on very

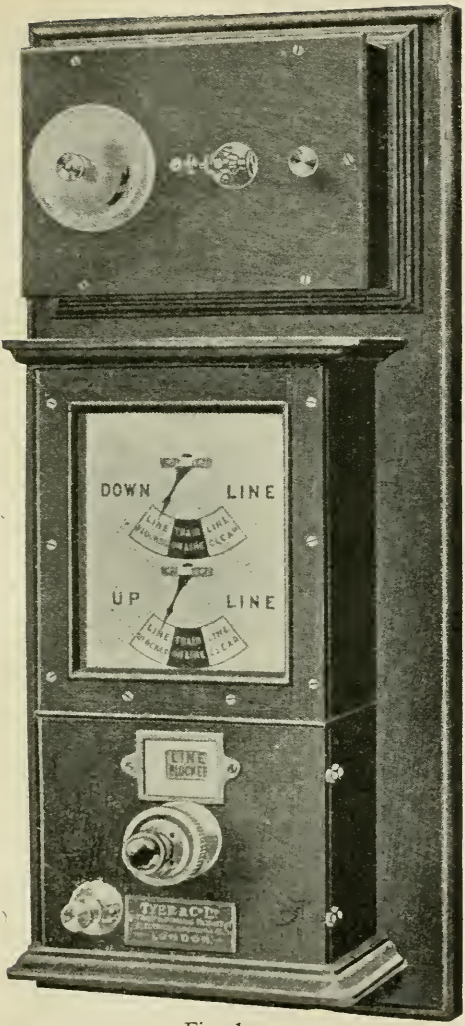


Fig. 1.
TYER'S PATENT ONE-WIRE THREE-INDICATION BLOCK INSTRUMENT.

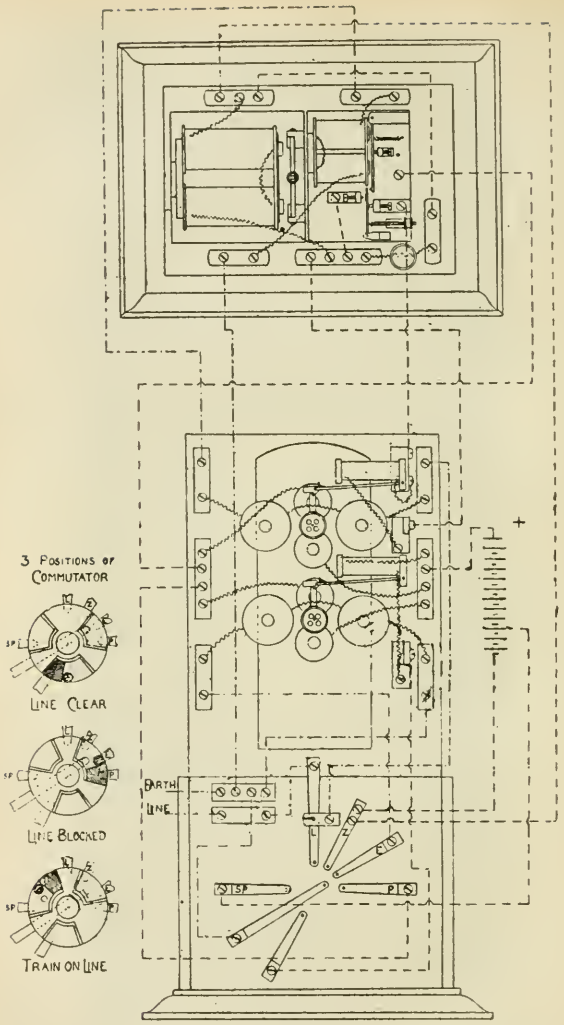


Fig. 2.
Diagram of Circuits for Tyer's One-Wire Three-Indication Block Instrument.

long circuits. In districts where there is very much corrosion it is advisable to use 150 lb. copper having a resistance of 5·85 ohms per mile, in order to save constant renewal of the line, or alternatively "Armco" Galvanized Iron Wire.

ONE-WIRE THREE-INDICATION BLOCK INSTRUMENT.

It is often necessary for Blocking back or shunting movements to take place, and it is undesirable for the needle to indicate "Line Clear" in the sequence movement, so therefore Messrs. Tyer's present well-known one-wire Three-Indication Block Instrument has been modified to allow of non-sequence working with ordinary direct momentary currents as hitherto, and is known as the Simple One-Wire Three-Indication Block Instrument (Figs. 3 and 4.)

Some of the Special Features of this Instrument are as follow :

1. Interlocking of Commutator with the plunger. This is so arranged that when the Commutator is turned from one position to another no further movement can take place until the plunger is pressed home and the Signal recorded, when the Commutator is again free. These turning movements are in either direction, and all signalling operations are easily manipulated with one hand.
2. The Commutator movement and locking of same till the plunger has been pressed home is of extremely simple design and constructed to withstand easily the continual use to which it is subjected.
3. The Indicating Needles are operated by means of twin armatures of Tyer's well-known cylinder pattern, and the entire needle movement is self-contained, being fixed to the ends of the steel cores of the electro-magnetizing combination by four screws, thus being easily detachable. The dial can be removed without affecting the adjustment of the needles, which are entirely independent of the dial.
4. It will be noticed that the "Line Blocked" position is placed centrally, thus conforming to the general practice. As previously stated, the indications can be given irrespective of sequence, thus, for instance, rendering it possible to place the needle directly to "Train on line" from the "Line Blocked" position when this is required.
5. Only one battery is required for each instrument, and there are no permanent currents flowing, the whole of the signalling being accomplished by momentary currents.
6. The instruments can be interlocked with Signal or Point Levers, and can be readily adapted for Lock and Block working, and the necessary parts added at a small extra cost.

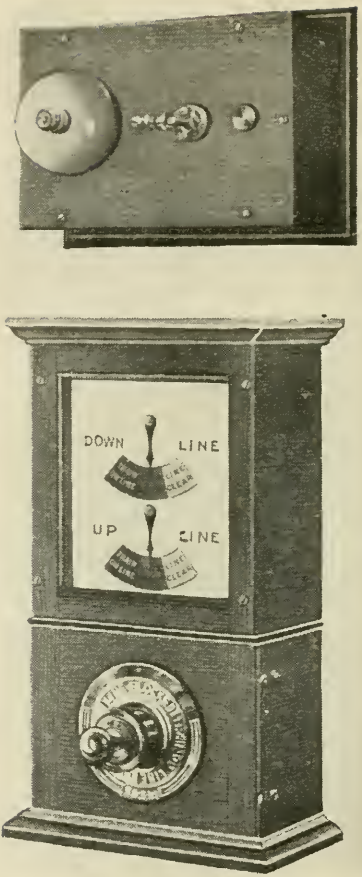


Fig. 3.

TYER'S ONE-WIRE THREE-INDICATION NON-SEQUENCE BLOCK INSTRUMENT.

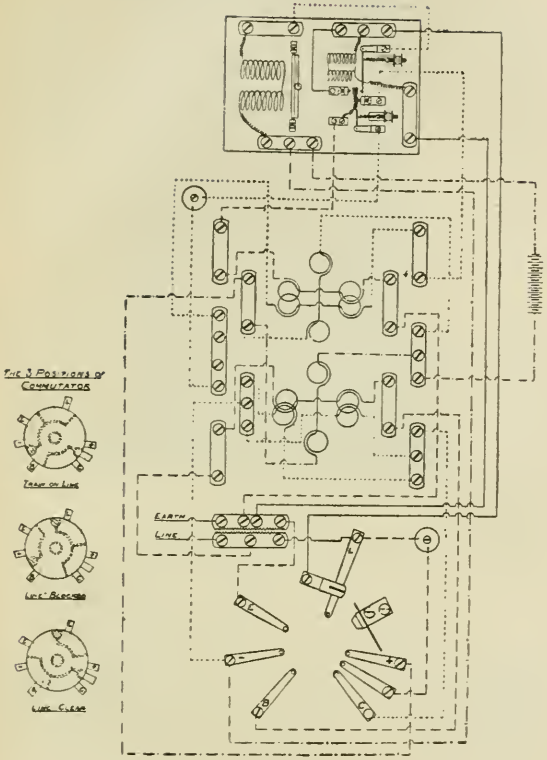


Fig. 4.

Diagram of Circuits.

One-Wire Three-Indication Block Instrument.

7. Briefly, the instrument is extremely simple in construction, will stand a great amount of use with very little wear, and, having no fine adjustments, is specially adapted for keeping in good working condition.

As these instruments are operated by strong currents for the " TRAIN ON LINE " and " LINE CLEAR " indications, and weak currents for the " LINE BLOCKED " indication, and the line currents in the " TRAIN ON LINE " and " LINE CLEAR " positions directly operate the needle movement, it is necessary to have low resistance windings for the needle movements, and this precludes the possibility of switching out stations without using balancing resistances to keep the working currents uniform. This, however, can be overcome by using special polarized relays of high resistance, thereby rendering the line resistance negligible which join local circuits operating the receiving needle movements, and by using suitable commutator connections for operating the sending needle movements locally.

PERMISSIVE BLOCK INSTRUMENTS.

Figs. 5 and 6 show Tyer's Permissive Indicating Block Instrument. Reading the diagram the following is a brief description :—

This instrument has been designed primarily for the purpose of indicating at each end of a section the number of trains occupying the section when working permissively. It can, however, be used for ordinary absolute block working by dispensing with the figures on the dial, and restricting the movement of the indicating needle to the right and left-hand movements of " Line Clear " and " Train on Line."

The chief advantage in using this type of instrument is that co-operation between the signalmen at each end of a section is essential before a signal can be transmitted.

METHODS OF WORKING.

Assuming that A has to proceed to B, signals by bell code are given on the tapper keys. If B is ready to accept the train, A turns his commutator handle in the direction of " Line Clear." No current can pass through his dial, however, until B also turns the handle of his commutator to " Line Clear." In a similar way when A signals to B " Train on Line," by bell code, no indication can be given on either dial until both the signalmen at A and B turn the handles of their respective commutators to " Train on Line," the indication for permissive trains being similarly obtained.

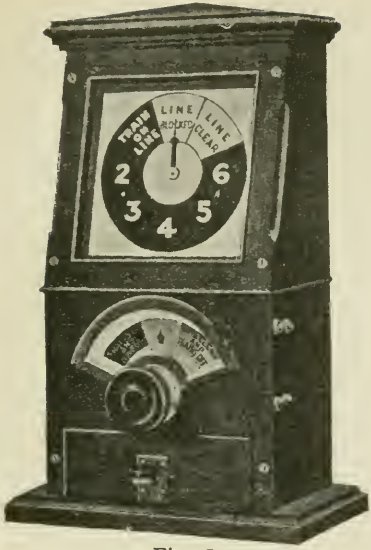


Fig. 5.

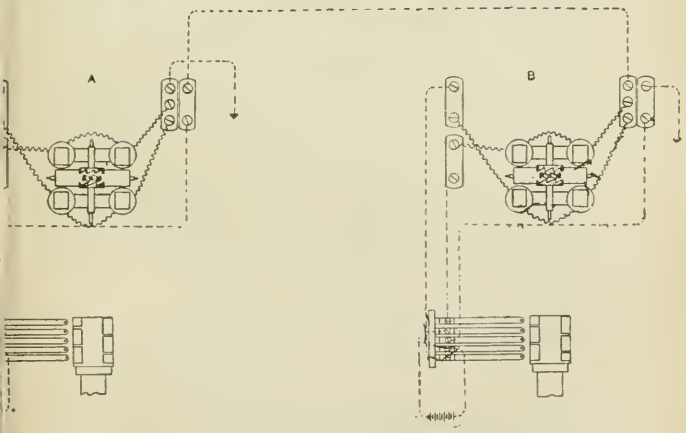


DIAGRAM OF CIRCUITS.

Fig. 6.

TYER'S PATENT PERMISSIVE INDICATING BLOCK INSTRUMENT.

TRAIN DESCRIBERS.

In order to inform a signalman of the origin or destination of approaching trains, train describers are often employed; particularly at busy centres.

A Tyer's train describer is shown in Figs. 7 and 8. The upper dial is the "receiving" one, whilst the lower dial is the "sending" portion. On the latter are holes into which the pin is placed opposite the signal required to be sent. By manipulating the button on the right side of the instrument, the commutator operates and causes a corresponding indication to be sent to the line. A single line wire is required for each set of apparatus, so that an instrument requires two wires altogether.

On the London Underground Electric Railways, magazine train describers are used, there being in many cases several block sections between adjacent signal boxes; this type of describer assists the signalman, who, otherwise, would have to trust to memory to set the correct routes.

When a train departs the signalman sends forward the description of the train, which is registered on a magazine, but as only one train indication can be shown at a time, the remaining indications are stored up. After the train has arrived, it automatically cancels its indication through the track circuits and the description of the next train at once appears.

This apparatus requires four line wires. If both up and down lines are equipped, there will be a total of eight line wires. These figures refer to four-stud magazine drums, so that in those cases where the train indications only require three or two stud drums the line wires are reduced to three and two respectively.

TYER'S ALTERNATING CURRENT ONE-WIRE THREE-INDICATION BLOCK TELEGRAPH INSTRUMENT.

This instrument, shown diagrammatically in Fig. 9, marks an advance in the science of Block Signalling. The three Block indications can be exhibited in any order precisely as in the case of three-wire Block instruments. Each of the three indications is produced by current, having a distinct characteristic, *viz.*:—

Negative direct current for "Line Clear."
Positive direct current for "Train on Line."
Alternating current for "Line Blocked,"
"Line Closed," or
"Train out of Section."

A permanent magnetic field is set up for each of the three indications, the magnetic field for one indication being different in direction from that for the other two.

There are no electro-mechanical devices necessary for controlling the needle in any position. The change of

direction in the magnetic field completely controls the needle in all three indications.

Each indication is therefore positively produced by a definite magnetic force. In three-wire systems one of the indications is produced by gravity in the absence of magnetic forces, so that supposing the indicators to be at "Train on Line," and a failure occurred, the effect would be to cause the indicators to show "Line Blocked," equivalent to "Train out of Section." In the case of this instrument, a similar failure would leave the "Train on Line" indication unaltered.

The instrument will operate efficiently over long or short sections without the use of balancing resistances. It is usually arranged on the same plan as the well-known three-wire Block Instrument, but the dial movement may be adapted to work an index of the single needle or disc type, while any style of commutator can be used.

Only one battery is required for each instrument, the whole of the signalling being accomplished by means of momentary currents.

The instrument can be readily adapted to all signal interlocking requirements, and can readily be fitted with the necessary parts for Lock and Block working.

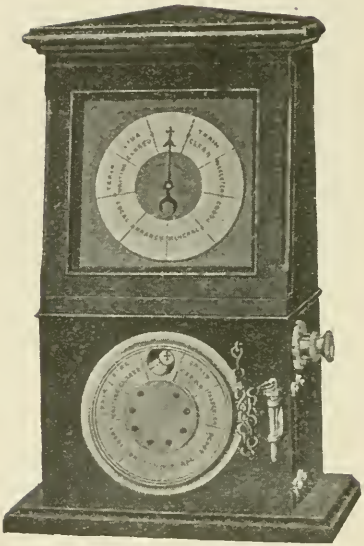


Fig 7.

Tyer's Patent Train Describer.

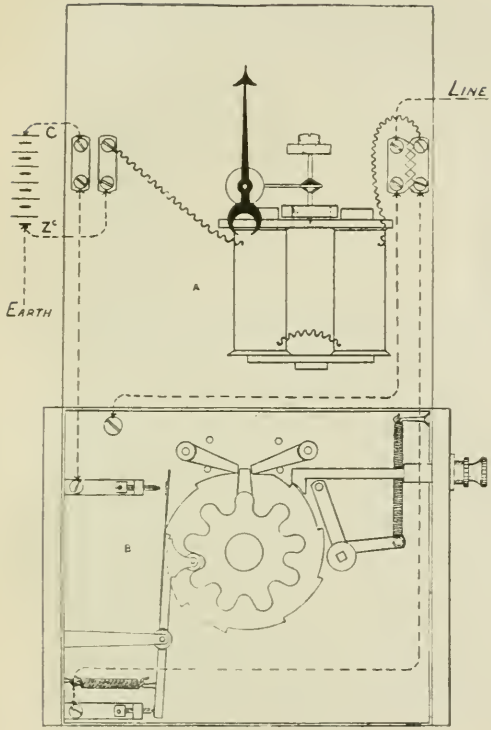
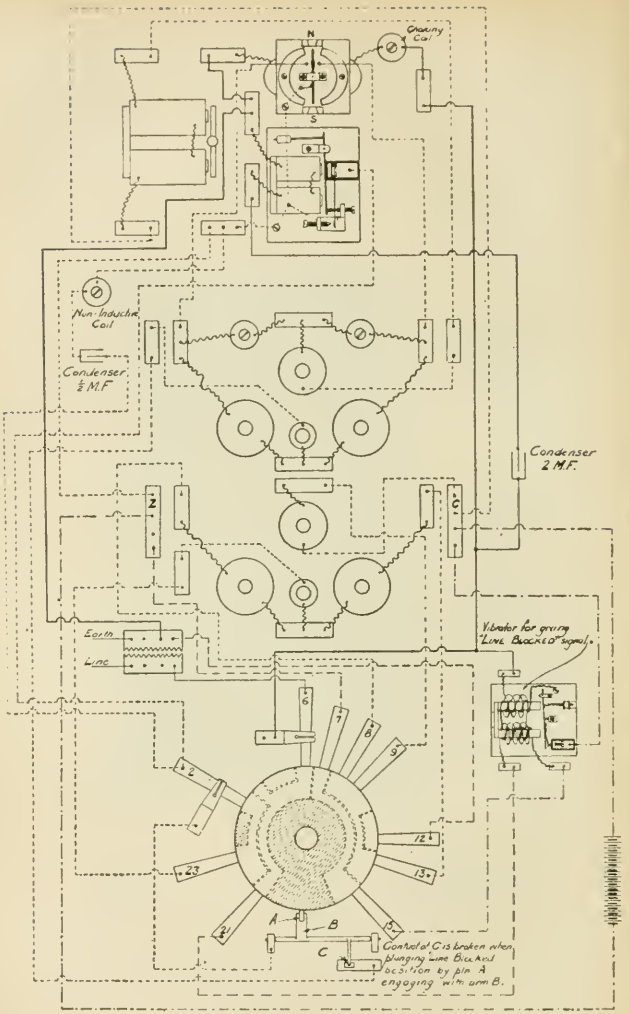


Fig. 8.

DIAGRAM OF CIRCUITS FOR TYER'S PATENT TRAIN DESCRIBER.



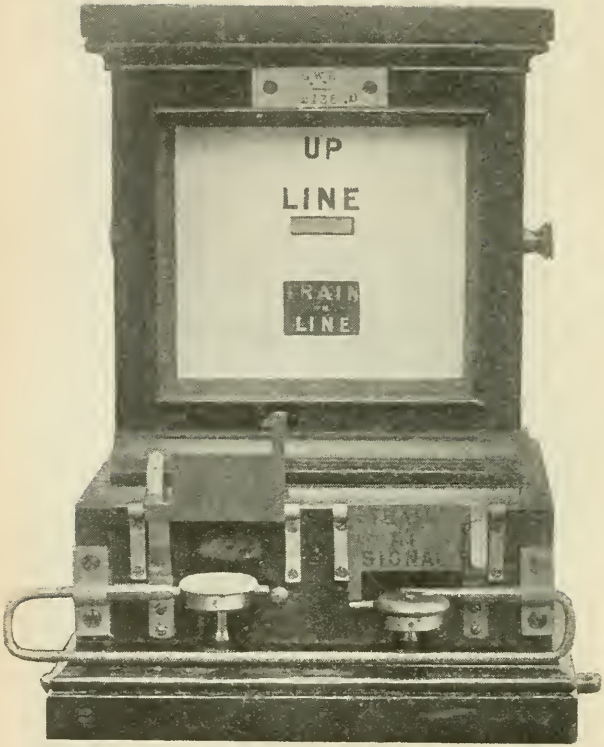
SPRINGS JOINED BY COMMUTATOR

Line Blocked Position	2 - 23 6 - 21 7 - 15 8 - 13 - 9	Train on Line Position	6 - 9 7 - 8 12 - 13	Line Clear Position	6 - 7 8 - 3 12 - 13

FIG. 9.

TYER'S PATENT ONE-WIRE THREE-INDICATION ALTERNATING BLOCK INSTRUMENT.

GREAT WESTERN RAILWAY—BLOCK INSTRUMENT.



GREAT WESTERN RAILWAY—BLOCK INSTRUMENT.

LOCK AND BLOCK.

In the "Lock and Block" system of train signalling, the outdoor signals are electrically interlocked with the block instruments, consequently a signalman is mechanically prevented from allowing two trains to be in a section at the same time. If either the signalman or the mechanism does not work correctly, the line is blocked.

The diagram (Fig. 1) shows Tyer's Patent One-wire Three-Indication Lock and Block, and the circuits for an intermediate cabin with crossover road. The locking is electrical throughout, and is controlled by relays. Normally relays D-D1 are energized from batteries 1-2, and the commutator locks F-F1 are free to allow commutators to be turned to "Line Clear." Assume A asks B to accept train, line being clear, A turns commutator of Block Instrument to "Line Clear" and plunges; relay D is de-energized, and commutator becomes locked after being turned to "Train on Line" position. B asks C to accept the train, and C in plunging "Line Clear" operates relay G, which is a polarized first current relay, and in turn energizes relay H; current passing from battery J; retaining H, and operating lock K on lever L, allowing starting signal M to be lowered. The pulling-over of lever L disconnects relay H, and L becomes back-locked. Train clearing station and passing over rail contact or track circuit at N energizes relay H, and allows lever L to be put to normal. The replacing of L again disconnects relay H, and energizes relay D, allowing commutator of block to A to be restored to "Line Blocked."

To obtain crossover lever, block instrument for opposite road must show "Line Blocked," and lever must be replaced before train can be accepted. All cancelling movements controlled by patent co-operation device on same line wire.

Figs. 2 and 3 explain in outline the working of the Sykes' system. The miniature block indicator has only two positions and this is the usual arrangement, but on the Great Eastern, the London, Tilbury and Southend section of the Midland Railway; also a portion of the S.E. & C. Railway, the system is installed with a three-position block indicator.

There are two important complements to the system. One is the provision of a releasing key as a means of releasing the signalman, should he get locked up, either by the failure of the rail contact, or other defect in the apparatus, or by the train not having gone forward; the other is the fixing of a replacer to the starting signal to prevent it being left "off," and so nullifying the whole security of the system.

Undoubtedly the possession of this key in the hands of the signalman is a considerable menace to the security of the interlocking, but if serious delays are to be avoided on busy lines some sort of cancelling arrangement is quite necessary. To overcome the illegitimate use of the key,

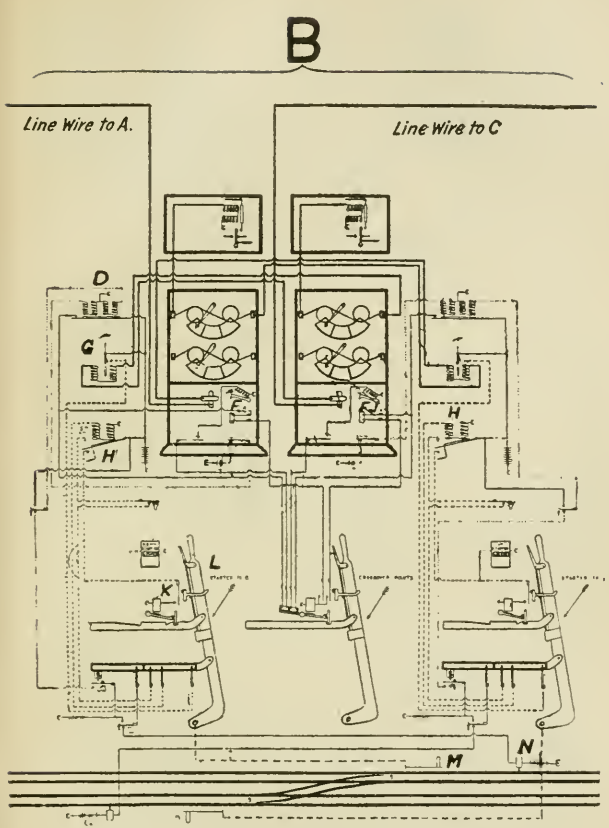
which has at times caused accidents, the controlled system of cancellation was introduced. This requires the co-operation of the signalman in advance before a release can be obtained, and, in some cases, the co-operation also of the signalman in the rear.

Even when a proper treadle release has been obtained, there is no guarantee that the whole of the train has cleared. For in the case of goods train, not fitted with continuous brake, the first portion might have cleared but the second portion have broken away and still remain in the section, nevertheless the block instruments would be cleared. Another point lies in the difficulty of deciding the best locations for the rail contacts.

In places where foreign currents are experienced, an arrangement has lately been introduced termed the "Duo-direction release," which requires two currents of different polarity to be received in pre-determined order to release the back-lock.

Figs. 4 and 5 illustrate another type of instrument, which is provided with a controlled system of cancellation interlinked with the block and equipped with "Veeder" recorders, so that it is quite impossible for a cancellation to be effected without the fact being known. Three line wires are necessary.

"Lock and Block" was introduced into the United States in 1881 and has since made considerable headway, being known there by the name of the "Controlled manual system."



COMPLETE DIAGRAM OF CIRCUITS FOR CABIN.

Fig. 1.

TYER'S PATENT ONE-WIRE THREE-INDICATION LOCK AND BLOCK.

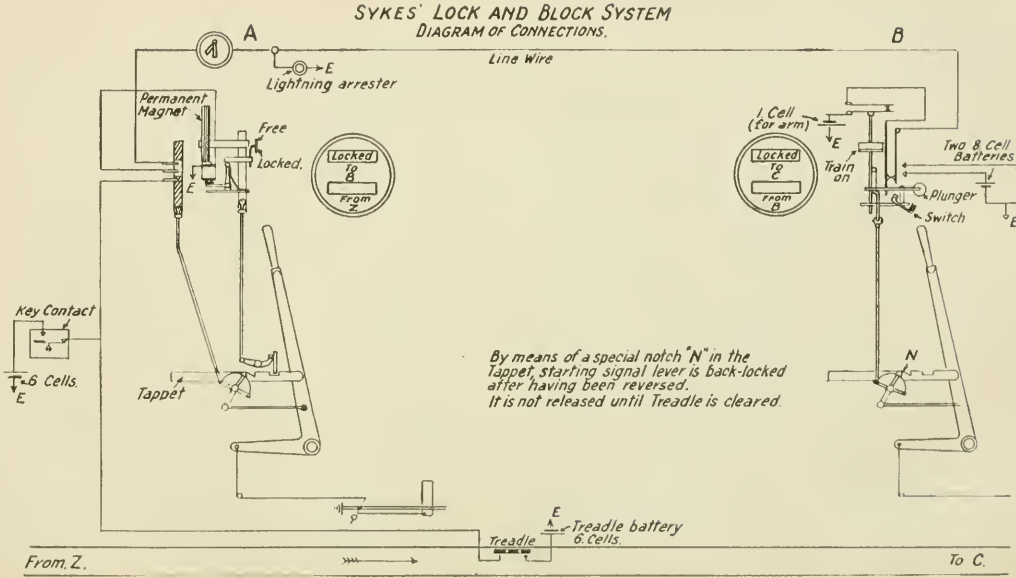

SYKES' LOCK AND BLOCK SYSTEM
DIAGRAM OF CONNECTIONS.
A
B
Line Wire
E
Lightning arrester
Permanent Magnet
Free
Locked.
Locked to 8 from Z
1 Cell (for arm)
Locked to C from B
Train on
Two 8 Cell Batteries
Plunger
Switch
Key Contact
6 Cells.
Tappet
By means of a special notch "N" in the Tappet, starting signal lever is back-locked after having been reversed. It is not released until Treadle is cleared.
N
Treadle battery 6 Cells.
Treadle
From Z.
To C.

Fig 2.

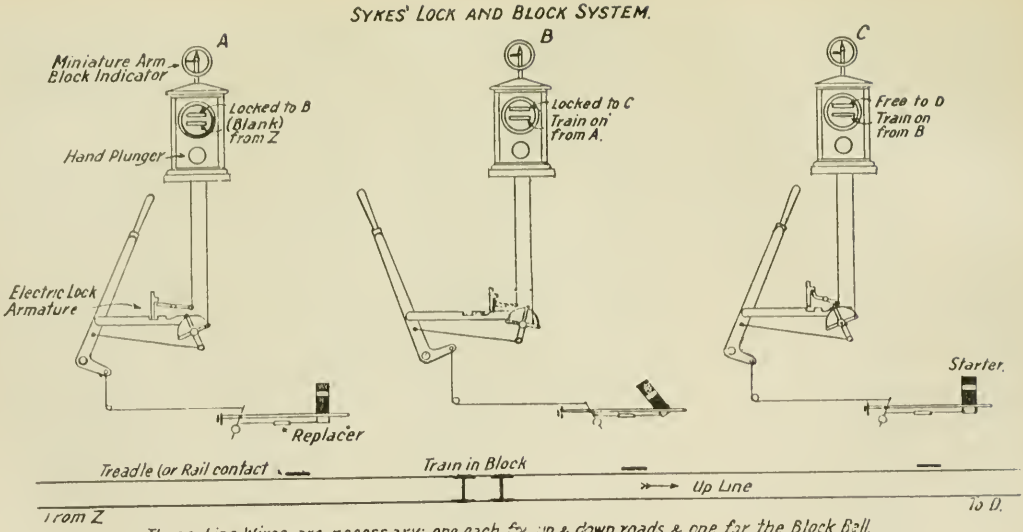
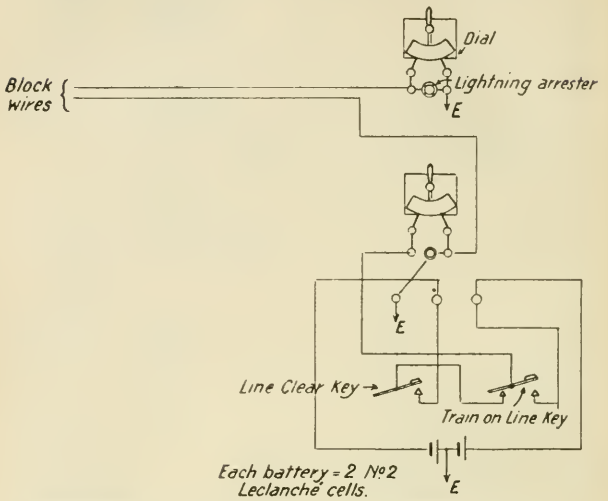
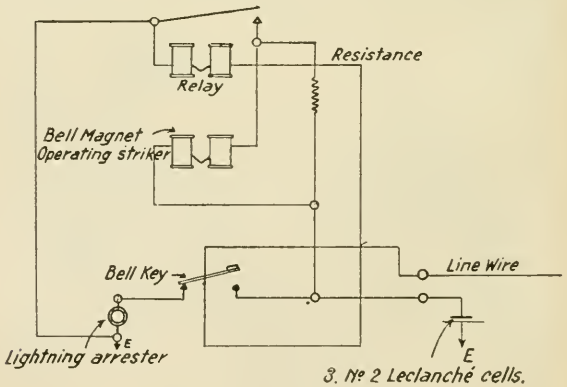

SYKES' LOCK AND BLOCK SYSTEM.
A
Miniature Arm Block Indicator
Locked to B (Blank) from Z
Hand Plunger
Electric Lock Armature
Replacer
B
Locked to C
Train on from A.
C
Free to D
Train on from B
Starter.
Treadle (or Rail contact
Train in Block
Up Line
To D.
From Z
Three Line Wires are necessary: one each for up & down roads & one for the Block Bell.

Fig. 3.

SPAGNOLETTI THREE-WIRE THREE-POSITION BLOCK.
DIAGRAM OF CONNECTIONS FOR DOUBLE DISC INSTRUMENT.



SPAGNOLETTI THREE-WIRE THREE-POSITION BLOCK.
DIAGRAM OF CONNECTIONS FOR TAPPER BELL.



Figs. 4 and 5.

SINGLE LINE WORKING.

The employment of electricity for the working of single lines is almost universal in Great Britain, the system used being either the electrical tablet or the electrical train staff.

There are several types of Tyer's tablet instruments, an example in extensive use being shown on page 152. Tablets are obtained from the lower slide, which can only be fully withdrawn with the permission of the signalman at the other end of the section. Tablets from arriving trains are inserted in the upper slide, which is then pushed home, thereby unlocking the instrument and permitting the passage of another train.

There are also permissive and automatic tablet instruments, and the description and working of these instruments will now be given.

ABSOLUTE OR PERMISSIVE TABLET.

This instrument has been arranged to combine " Absolute " and " Permissive " working, and is especially useful where there are long sections, which under absolute block working would entail a great loss of time to a following train to wait until the previous train had reached the end of the section. It is possible with this instrument, under certain conditions, and with the direct consent and co-operation of the men at each end of the section, to take out any number of tablets up to forty-seven and thus allow forty-seven trains to run " following," the indicator on the instrument showing the number of trains in this section. Each driver is warned that he has another train in front of him, and as an additional reminder the tablet is placed in a special pouch of Red enamelled leather, with a triangular loop, to denote " Permissive " working. It is quite impossible for tablets to be issued except as authorized and when once a tablet or tablets are withdrawn, no tablet can be obtained at the other end of the section for a train coming in the opposite direction until all the trains for which tablets have been issued have arrived, and the tablets have been inserted in the instrument at the other end.

It is possible to cancel " Permissive " working of any train not proceeding, but for which a tablet, or tablets, have already been withdrawn, by restoring same to their original instrument ; this cannot take place except by co-operation of the man at the other end of the section who, for every tablet that is returned to the instrument, will turn the commutating portion of his instrument backwards, *viz.*, from left to right, which will cancel the right to left movement when he gave permission to obtain the tablet, so that both operators, therefore, have a complete record at any time of the state of the road, how many trains are following, etc.

In "Absolute" working only one tablet for a section can be out at the same time; and in "Permissive" working a second and subsequent tablets may be withdrawn, although the first has not been placed in the instrument at the other end of the section.

TYER'S NO. 5 ABSOLUTE OR PERMISSIVE TABLET INSTRUMENTS.

OUTLINE OF WORKING—PERMISSIVE.

A intimates to B, as per code, that he requires to send a number of trains in one direction.

B replies as per code.

A depresses his plunger marked BELL.

B depresses his plunger marked SWITCH, and at same time turns the gun-metal knob G from right to left.

B lifts the lid H and removes the tablet from the instrument, withdraws slide S, inserts the tablet and pushes slide home; he then depresses to the full extent the gun-metal knob G, which will have the effect of disconnecting the carriage portion of the instrument from the commutating portion, and at same time locking slide S, containing the tablet, inwards.

A again holds down on his BELL-PLUNGER.

B depresses the SWITCH-PLUNGER and at same time turns his gun-metal knob G from right to left (which moves the commutating portion of the instrument only) thus altering his commutator so as to coincide with A's instrument.

B gives A permission to obtain a tablet for the first train.

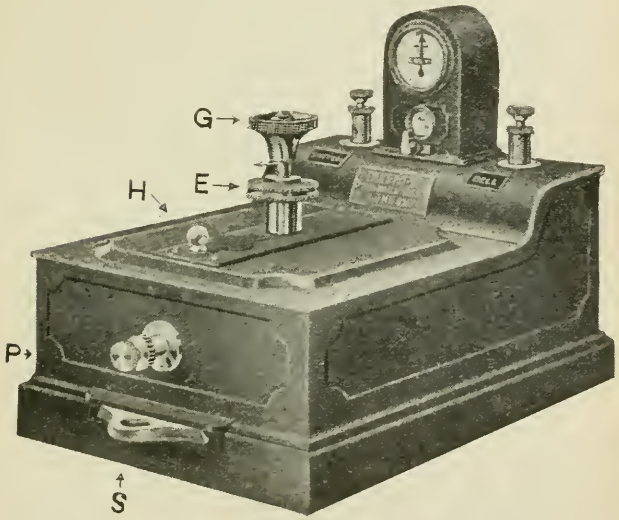
A calls B for a second tablet, and B, holding down his SWITCH-PLUNGER, can turn his gun-metal knob and commutating wheel so that it again coincides with A's machine, thus allowing B to give A permission to obtain a second tablet, and so on for any number of trains.

Upon the arrival of each train B upon receiving the tablet will lift lid H; insert the tablet in machine, and turn the gun-metal engraved knob E to the left; this does not require a current from A, the tablet mechanically unlocking the carrier portion of wheel.

Each forward movement B makes with his commutating portion, takes the key on the centre spindle farther away from the key-way in carriage of machine, so that every train which leaves A must arrive at B and all the tablets be inserted into the machine there before the key-way in carrier portion can overtake the key on centre spindle (which has been working for commutating wheel) and so allow the key to enter. When this takes place, the key enters the key-way and the two wheels become rigid; the spindle rises by slightly pressing the slide S, and the slide can be withdrawn with the tablet. This tablet must be inserted into the machine before the commutators of A and B's instruments will coincide, ready for absolute or permissive working to again take place from either end.

The cancelling of any train, or trains, not proceeding, but for which A has already obtained a tablet, or tablets, cannot take place without B's permission, and for every tablet A returns to his instrument B must (by A's permission) turn his commutating portion one tooth backwards, *viz.*, from left to right, which will cancel the right to left movement when he gave A permission to obtain the tablet.

Both in absolute and permissive working, the small plunger P on front of case must be depressed after each manipulation of the instrument; this plunger operates upon two mechanical pawls working in the teeth of wheels, which are fitted to prevent the possibility (during quick working) of tripping taking place, when either electro-magnet governing the main locking pawls is energized.



Tyer's Patent No. 5 Absolute or Permissive Tablet Instrument.

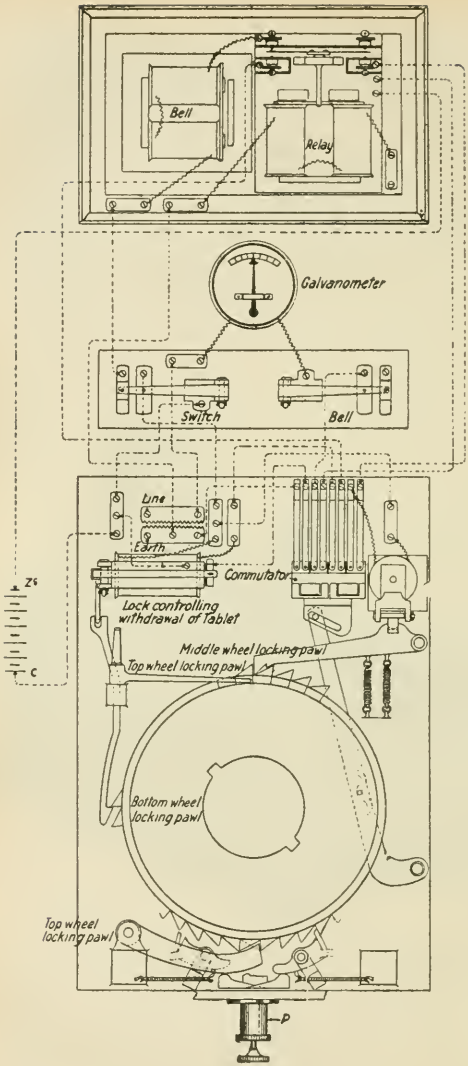


DIAGRAM OF CIRCUITS.

TYER'S PATENT NO. 5 ABSOLUTE OR PERMISSIVE TABLET INSTRUMENT.

TYER'S PATENT NO. 6 TABLET INSTRUMENT.

This instrument is fitted with a block dial having two indicators and galvanometer The upper disc indicates the state of the section for traffic in (what is for the time being) the advance end of the section, whilst the lower disc shows the commutator has been turned, and a tablet withdrawn for a train to depart from the home end of the section, and also shows when such train has arrived at the distant end of the section, and has been cleared. The commutator is interlocked with the main slide, and all its movements are controlled by the distant operator.

Illustration of Working Section.

A————————————————B

A has a Passenger train ready to enter section and proceed towards B.

A gives three beats on bell or gong, and, after receiving the acknowledgment from B, he transmits the Train Tablet Signal.

B replies by one beat, and holds down his plunger for the purpose of unlocking A's Commutator.

A reverses his Commutator from right to left by means of the large gun-metal knob, and exhibits the signal Out on his lower disc ; he then withdraws his slide with a tablet, and gives B one beat, which will turn B's upper disc from In to Out, and thus both discs will be in unison.

A will hand the tablet to the engine-driver, and give the Departure Signal.

B will reply by repeating the same.

Upon the arrival of the train at B, the signalman will withdraw his slide empty, insert the tablet, push the slide home, and give the Arrival Signal. This will unlock A's Commutator.

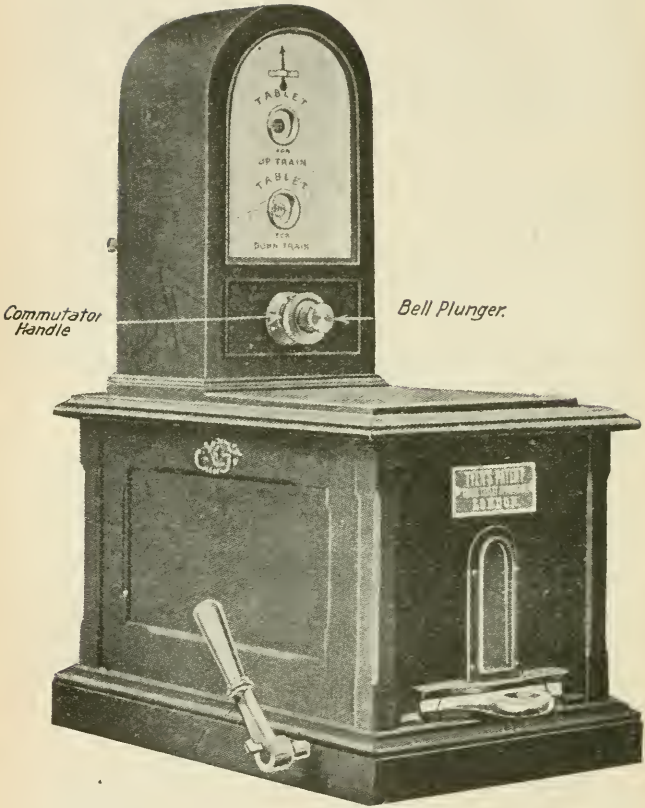
A will turn his Commutator from left to right, and give the Acknowledgment of Arrival Signal. This will have the effect of reversing the upper disc at B from Out to In, and prove to B that A has duly received the Arrival Signal, and has acted upon it. B will give one beat in reply, which will also reverse the lower disc at A, and prove likewise to A, that B's machine has been restored to its normal condition.

Both machines will then be ready for further working.

SHUNTING.

When a tablet (after having been used for shunting purposes) is returned to the cabin, and replaced within the machine whence it was taken, the Commutator will be unlocked, the signalman will then turn it from left to right, and transmit to the distant cabin the Arrival Signal, and, after receiving the acknowledgment, will give one beat.

The man at the distant cabin will give the Acknowledgment of Arrival Signal, and after receiving one beat in reply, both machines will be restored to their normal condition.



TYER'S PATENT NO. 6 TABLET INSTRUMENT.

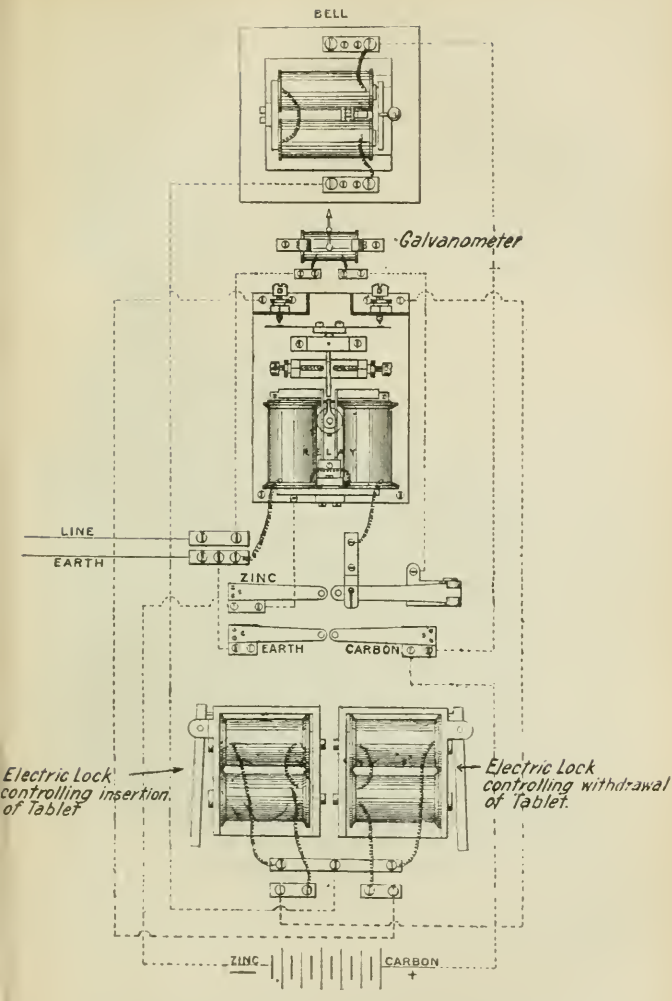


DIAGRAM OF CIRCUITS.

TYER'S PATENT NO. 6 TABLET INSTRUMENT.

TYER'S PATENT No. 7 TABLET INSTRUMENT.

This instrument is fitted with three indications showing LINE CLOSED, "UP" or "DOWN" TRAIN APPROACHING, and "UP" or "DOWN" TRAIN ON LINE, the two latter indications being shown according to whether the train is proceeding in Up or Down direction. There are three positions of the main slide which correspond with the above indications; *viz.*, normal as shown; slide half drawn, which is a train approaching position, and slide fully drawn, which is a train on line position.

OUTLINE OF WORKING.

A————————————————————B

A holds down on his BELL-PLUNGER.

B depresses his SWITCH-PLUNGER with his left hand, and at same time withdraws lower slide with his right hand. The withdrawal of this slide (which can be half way) will reverse the commutator in instrument, and will bring the signal UP TRAIN APPROACHING in view.

B will then depress his BELL-PLUNGER, holding down same for a few seconds.

A upon receipt of this signal will hold down his SWITCH-PLUNGER with his left hand, and withdraw his main slide to its full extent with his right hand, which will bring the signal UP TRAIN ON LINE.

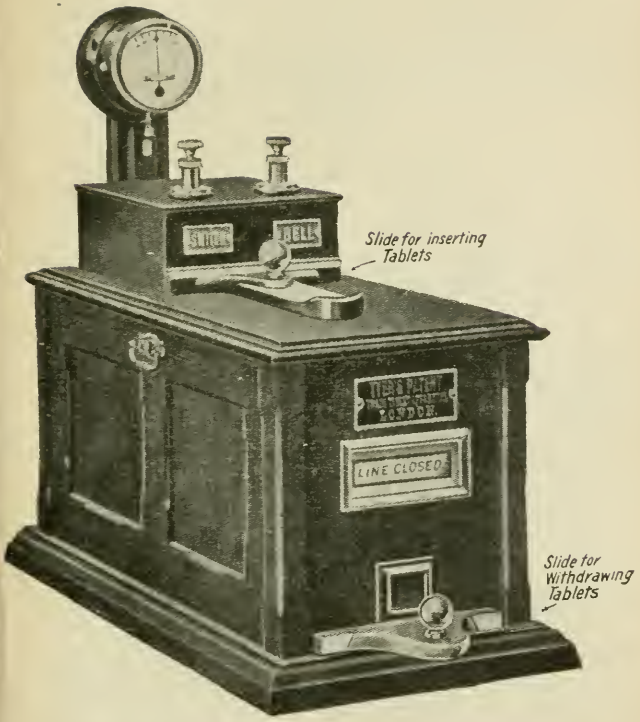
A will remove the tablet from recess in slide, and hand same to engine driver.

A gives DEPARTURE SIGNAL to B.

As soon as the train arrives at B, B withdraws the upper slide, inserts the tablet, and pushes slide home

The passing of the tablet into the cylinder unlocks this instrument, and B then pushes in the main slide, which restores his visual signal to LINE CLOSED; he will then give A the ARRIVAL SIGNAL holding down on the last beat. A, upon receipt of ARRIVAL SIGNAL, will depress his SWITCH-PLUNGER, and push home his main slide, which will at the same time restore his visual signal to LINE CLOSED.

For a tablet taken out for shunting, or for the purpose of entering some intermediate siding, and returned to the station whence it was issued, the manipulation of the machines is practically the same.



107 Tablet Instrument

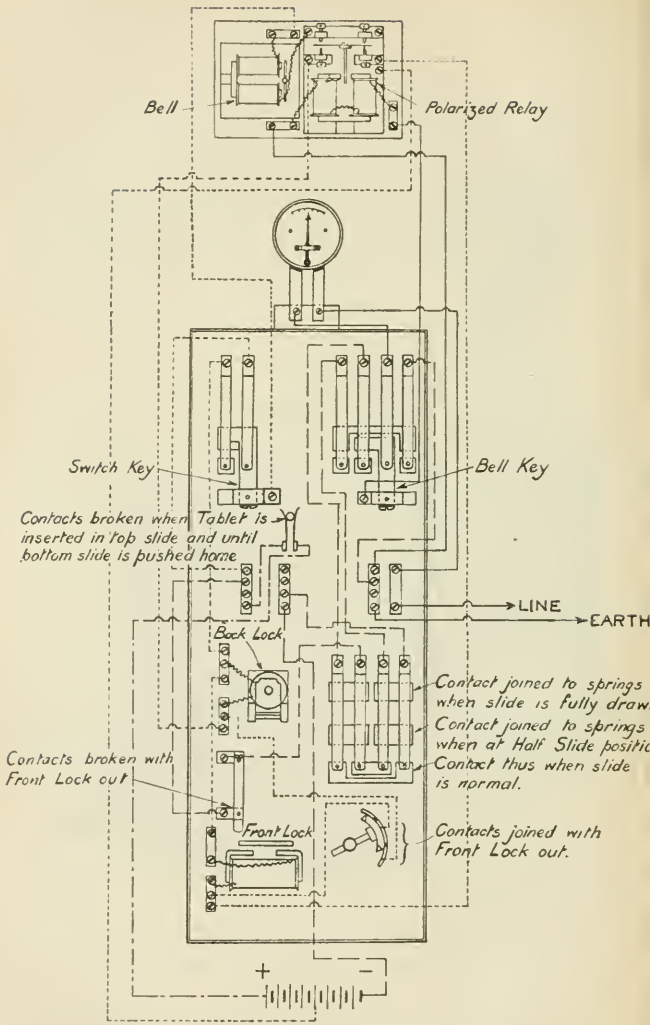
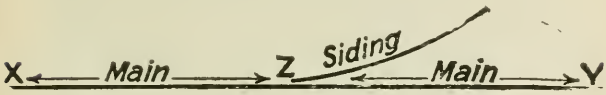

Bell
Polarized Relay
Switch Key
Bell Key
Contacts broken when Tablet is inserted in top slide and until bottom slide is pushed home
LINE
EARTH
Back Lock
Contact joined to springs when slide is fully draw
Contact joined to springs when at Half Slide positio
Contact thus when slide is normal.
Contacts broken with Front Lock out
Front Lock
Contacts joined with Front Lock out.
+
−

DIAGRAM OF CIRCUITS.

TYER'S PATENT NO. 7 TABLET INSTRUMENT.

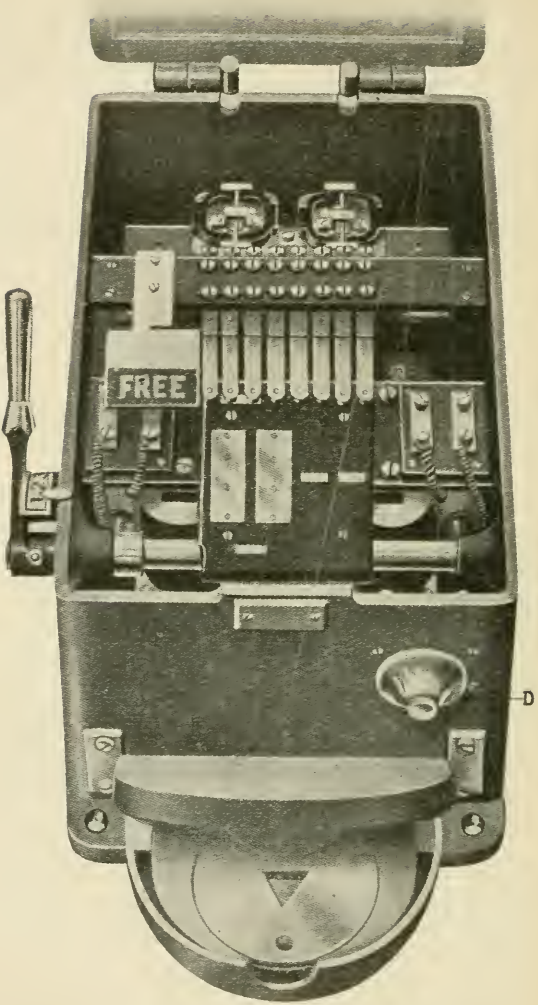
TYER'S PATENT INTERMEDIATE TABLET INSTRUMENT.

This instrument is designed to work on the same line wire as Tyer's No. 7 Tablet Instrument, and is used where facilities are required for entering sidings, branch lines, etc., at any intermediate point in a block section.

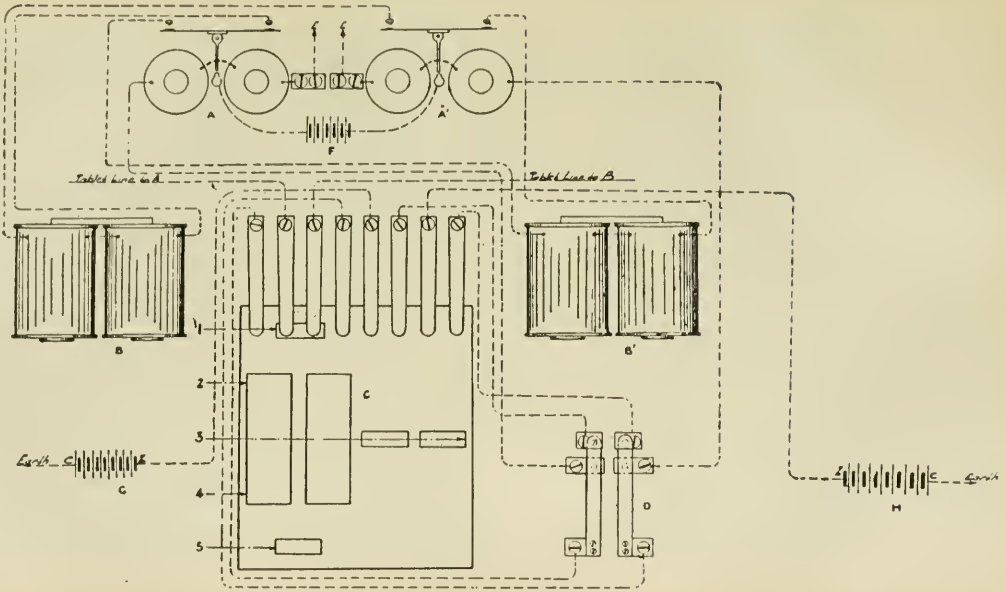


Method of Working Section.

A train leaves either X or Y for the siding Z; arriving at the siding the tablet is first used to unlock the point lock controlling the siding lever. When train is clear of main line tablet is withdrawn from lock and inserted in instrument, the handle of same being pulled to No. 2 position. Z calls up X and Y by 'phone and X and Y send signals on their tablet instruments, which allow Z to pull handle to No. 3 position. In this position plunger D is depressed, which allows X and Y to restore the tablet instruments to normal, after which they both send current to Z, which allows handle to be pulled to No. 5 position, in which the tablet is completely locked in the instrument, and the line wire being switched through, tablet working can be resumed between X and Y. To release the tablet at Z, X and Y must be normal and send current to Z, who pulls handle to No. 3. Z then presses plunger D, and sends current to X and Y, who each withdraw tablet slide half way, *viz.*, train approaching. X and Y send current to Z who pulls handle to No. 1, and removes tablet. Tablet is then used to unlock points and after same are put back clear of main line, train can proceed to either X or Y—tablet being inserted in either instrument clears the section.



TYER'S PATENT INTERMEDIATE TABLET INSTRUMENT.


A
A'
F
Tablet Line to A
Tablet Line to B
B
B'
1
2
3
4
5
C
Earth
G
D
E
Earth

THE ELECTRIC OCCUPATION SYSTEM FOR SINGLE LINES WORKED BY ELECTRIC TABLET OR STAFF.

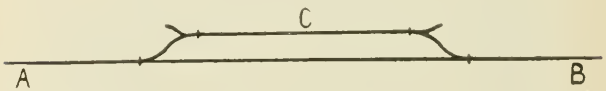
INCREASED FACILITIES FOR WORKING TRAFFIC OVER SINGLE LINES.

The Electric Occupation system which has now been introduced on several of the largest and most progressive railways in the United Kingdom, constitutes the most important development in connection with the working of single lines of railway since the introduction of the electric tablet system.

The Electric Occupation system dispenses with the necessity for flagmen in connection with engineering operations, and it enables trains to pass each other at sidings on single lines without having to make such places block posts.

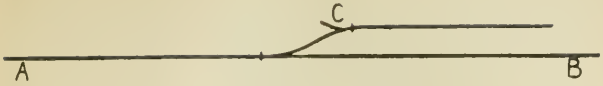
The following are typical cases where the electric occupation system can with advantage be adopted. These cases are in actual operation to-day.

CASE I.



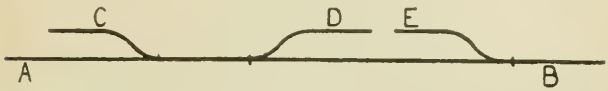
A—B represents a section of single line of railway worked on the electric staff system. This line is being converted into a double line and C is an intermediate siding to and from which contractors' trains are required to be run for the purpose of getting out materials, ballast, etc. In the ordinary way it would be necessary to provide a block post at this siding, or whenever it was necessary to come out of, or go into, the siding, a token would have to be taken to and from the siding, entailing considerable delays. By the introduction of the electric occupation system the necessity for either of these alternatives disappears. An occupation instrument with an occupation key is provided at the siding. Normally the key is locked in the instrument. To get out of the siding the key must first be obtained to unlock the points, and the key can be obtained with the consent of the signalman at A and B, provided no staff is out. So long as the key is out of the occupation instrument a token cannot be withdrawn at either A or B. In this way the contractors' train can occupy the single line immediately the line is clear of the ordinary trains, and the token circuit is again available for use for the ordinary trains immediately the contractors' train is safely locked in the siding.

CASE II.



Here A—B represents a section of single line worked on the electric tablet system. C is a junction leading to a colliery line. A train leaves A for the colliery line, taking with it a tablet or occupation key. At C an occupation instrument is provided, and when the train is on the colliery line, and clear of the single line, the tablet or key is placed in the occupation instrument and the electric tablet circuit is ready for the passage of through trains. When the train requires to return, or to go on to B, the tablet, or key, must first be obtained, and this can only be done with permission of the signalman at A and B, provided all the tablets are in the instruments.

CASE III.



In this case C, D, E are intermediate sidings on a long tablet section. A train leaves A, having work to do at each siding; the train first calls at C, and when there the line is required for a through train from B to A. When the train is in the siding clear of the single line the tablet or key is placed in the occupation instrument, and a tablet can then be obtained for the through train.

CASE IV.

A—B is a section of single line worked on the electric tablet system. This line is maintained by a permanent way gang, provided with a manual trolley capable of getting up a very considerable speed. C, D, E, F, G and H are occupation instruments fixed at about equal distances apart. The gang is at, say, C, at which place an occupation key is in the instrument, and requires to get to F. The ganger, with the permission of the signalmen, provided all the tablets are in the tablet instruments, obtains the occupation key. This is his authority to occupy the line,

and, having got the key, he puts on the trolley, and runs it to near the point at which occupation instrument F is fixed. So long as he holds the key a tablet cannot be withdrawn from either of the tablet instruments at A or B, and, therefore, it is not necessary for flagmen to be put out on arrival at F, and after putting the trolley off the line, the ganger inserts the key in the instrument at that point, and having done so informs the signalmen, who are then free to withdraw tablets in the usual way.

If the ganger wants occupation to take out a rail, he can again dispense with flagmen if he obtains the key.

The great advantage of the occupation system, is that the electric tablet system can be restored by the insertion of the key in any one of the occupation instruments on the section, while occupations can be safely and instantly arranged with the traffic staff.

These increased facilities for arranging occupations, running trolleys, and the saving of the flagmen admit of a permanent-way gang looking after a longer length of line than would otherwise be possible, and, in consequence, 20 per cent. can be saved in the wages bill of the permanent-way staff.

TYER'S
KEY TOKEN APPARATUS.

This apparatus is as shown in the accompanying illustration. It consists of a Galvanometer indicating the passage of Line Currents, a Bell Plunger, and also the Key Token, which itself reverses the Commutator, and is the permit for the driver to proceed.

A Bell, or Gong, is provided with the instrument.

Outline of Working.

Let A and B represent two stations.

A wishes to send a train to B.

A calls B as per code.

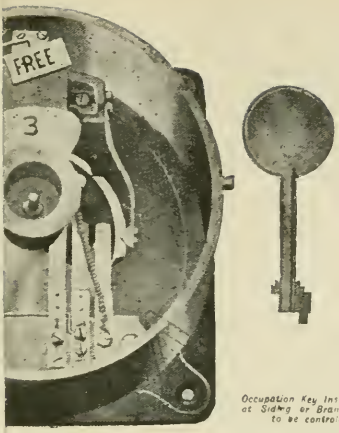
B replies as per code, holding down for a few seconds on the last beat.

A lifts the Key Token from the magazine, inserting it in the axis of the Commutator. If the current received from B is of the right polarity, the Electric Lock is released, the Commutator and Key Token are turned on their common axis in an anti-clockwise direction through an angle of 180 degrees, and the Key Token is withdrawn from the instrument and handed to the driver.

A gives the departure signal to B.

The two instruments are then out of phase, so that a second token cannot be withdrawn.

On the arrival of the train at B, B inserts the Key Token in the axis of the Commutator, and turns the two in a clockwise direction through an angle of 180 degrees; the Key Token is then withdrawn from the axis of the Commutator and placed in the Magazine



Occupation Key Instrument at Siding or Branch Line to be controlled

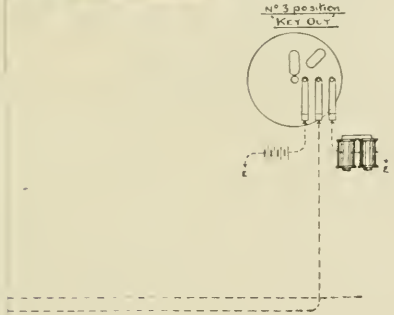
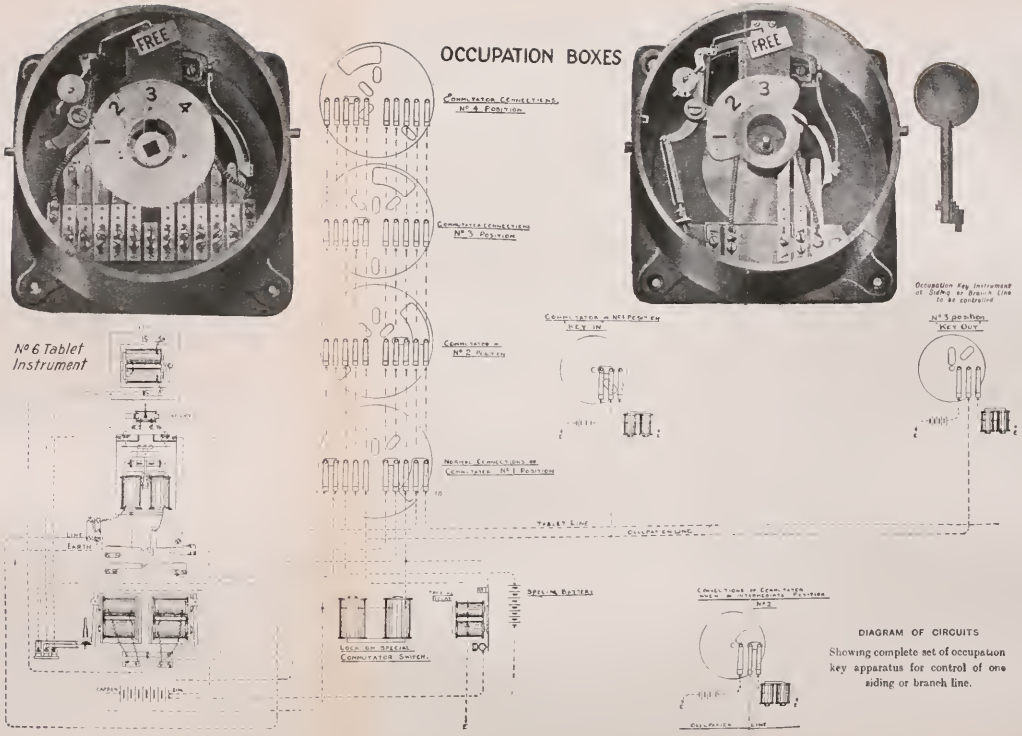


DIAGRAM OF CIRCUITS

Showing complete set of occupation key apparatus for control of one siding or branch line.



Facing page 160]

B gives the arrival signal to A.

Both instruments are now in phase, and a token can be withdrawn from one end or the other.

The following are some of the advantages of the above apparatus.

This instrument is extremely simple to operate and easy to maintain. It is absolutely fool-proof, tampering being impossible.

The instrument is neat and compact. It has only one moving part, *viz.*, an electrically-controlled rotary Commutator, which during the process of rotation forms, with the Key Token, a single mechanism.

A Key Token can be restored to the instrument from which it was withdrawn, after having been used for shunting, etc.

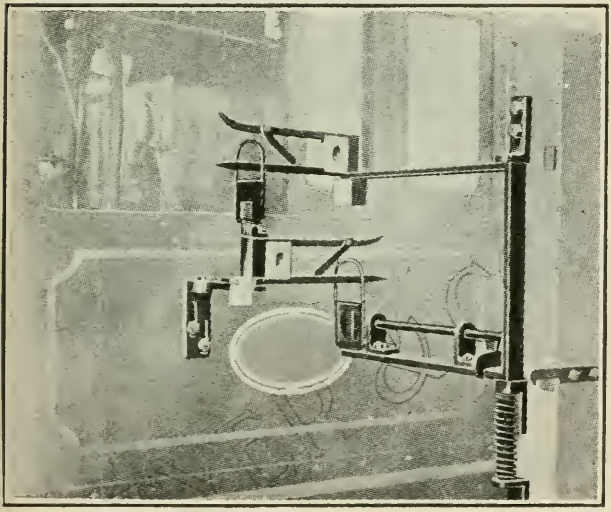
Small amount of battery power

Single line wire.

No permanent currents.

A minimum of parts and a minimum maintenance.

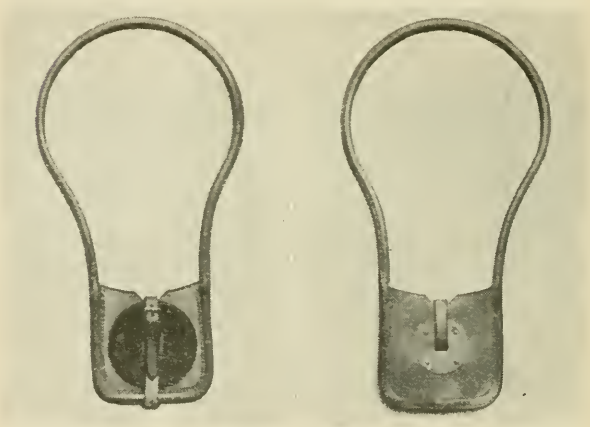
This instrument can, if desired, be arranged to work on the same electrical principle, and give similar visual indications as to the state of the line, as Tyer's Patent Automatic Tablet Instrument.



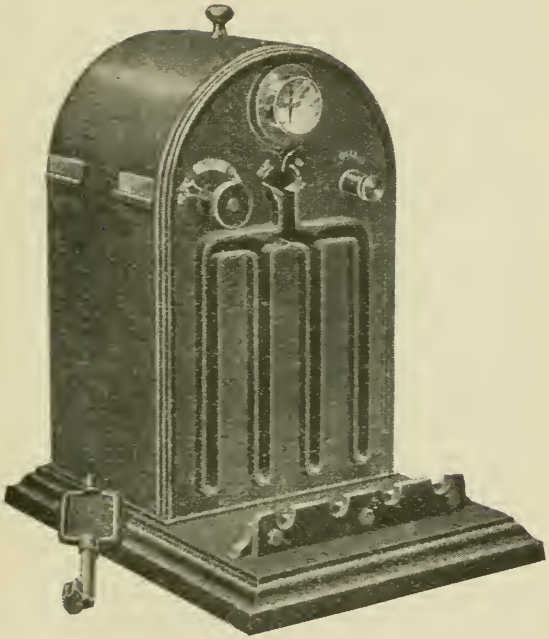
TYER'S PATENT TOKEN EXCHANGER.

For the preservation of the tablets or tokens, and to facilitate their handling, they are carried in leather pouches. Train staffs and tablet pouches are usually equipped with large catching rings so that they may be picked up and set down at speed. Automatic tablet exchangers are coming extensively into use, enabling tablets to be exchanged at speed of 45 miles per hour. The illustration shows one of the types of exchangers supplied by Messrs. Tyer & Co. (Page 163.)

Messrs. Tyer have also devised a very compact and simple form of Tablet Pouch, and, as seen in the illustrations, the reading on the tablet is seen at a glance, and further, the tablet for the proper section can only be inserted in the tablet pouch appertaining to that section. In other words, tablets with round, square or triangular configuration are non-interchangeable, which is a great step in the right direction towards ensuring the safest possible single line working.



TYER'S TABLET POUCH.



TYER'S PATENT KEY TOKEN INSTRUMENT.

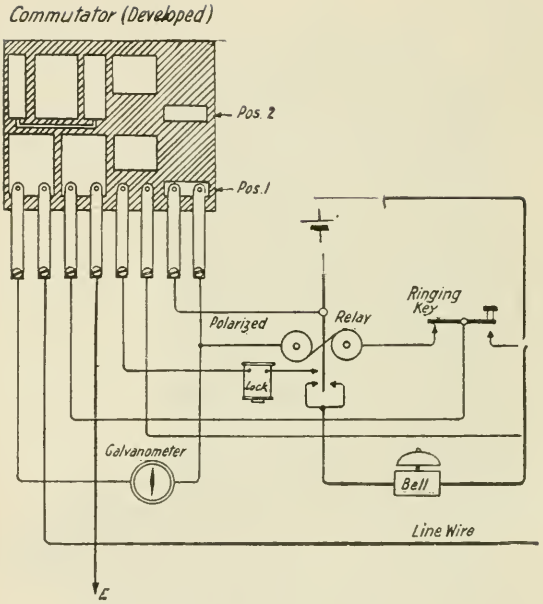


Diagram of Circuits.

Tyer's Patent Key Token Instrument.

CAB SIGNALLING AND AUTOMATIC TRAIN CONTROL.

Probably more attention has been directed to this subject than to any other railway safety appliance.

While the need for some method of repeating the semaphore signals in the engine cab is most acutely felt when fog or snow prevails, the desirability of providing some reliable form of cab signalling combined with automatic train control under all weather conditions can hardly be questioned.

Nearly forty years ago Messrs. Lartigue & Forest, of the Northern of France Railway, introduced insulated ramps or " crocodiles " in the four-foot way, which, when the Distant signal is at " Danger," allow a current of electricity to be picked up by an apparatus on passing engines, thus opening a steam whistle on the engine and warning the driver.

Many inventors have sought to produce distinctive cab signals for " Danger " and " Clear " by mechanical means, but there are strong inherent objections to this method, as it involves some form of moving apparatus on the track.

Several systems of inductive or wireless control have also been, or are being, tried, one of which (the " Prentice " system) is actually in use in Canada.

Some of the principal objections and conditions, failure to comply with which render impracticable the vast majority of the patented systems, are :—

1. The use of moving ground apparatus, on account of snow and frost and other difficulties.
2. The use of an electric current to *produce the "Danger" signal*, as failure of the apparatus would suppress the " Danger " signal.
3. Wireless or inductive systems depending on delicate electrical apparatus have hardly yet proved reliable enough for all-round everyday working.
4. In addition to giving a distinctive audible signal for " Danger " and " Clear " respectively, to be satisfactory the apparatus should also apply the brake.
5. A satisfactory system should not embody any apparatus which interferes with the continuous look-out ahead on the part of the driver.

Under the " Prentice " system of inductive control a copper conductor is laid in wooden troughing between the rails. When the track is clear this conductor is fed from a small sub-station with Hertzian waves, which are, however, cut off, should the track be occupied. Attached below the engine is a row of wires about two feet from the ground conductor, and through these the Hertzian waves are conducted to suitable control apparatus in the engine cab. When the track is occupied no current is received on the engine, and a red light is exhibited, and the brake gradually applied, but so long as the track remains clear the current

received restrains the danger signal, and a green light is exhibited. As the apparatus may get out of order or the engine may have to run over sections of line not equipped, the driver is given means for permanently restraining the application of the air brake, and while this portion of the apparatus is cut out, the red light remains showing in the cab.

The only two cab signalling systems which are in actual daily use on British Railways are the Combined Automatic Train Control and Audible Signal system, which is now in operation on fhe G.W.R. on 187 miles of track, and was first introduced in 1906, and the Raven Cab Signalling Apparatus, which is installed on 46 track miles of the North-Easern Railway.

A general description of each of these systems with diagrams is given below, from which it will be seen that while in some respects there is similarity between the two systems, the one in operation on the G.W.R. is simpler than the Raven system.

GENERAL DESCRIPTION OF COMBINED AUTOMATIC TRAIN CONTROL AND AUDIBLE SIGNAL SYSTEM IN USE ON THE GREAT WESTERN RAILWAY.

The primary object of this system is to give an audible warning on the engine when the train is approaching a Distant signal in the " Stop " position, and in the event of this warning being disregarded to automatically apply the brakes so as to ensure the train being pulled up before it reaches the Home signal.

Another and distinctive audible indication is also given on the engine when the Distant signal is at " Proceed." The value of this latter indication is that it facilitates the running of the train when the line semaphore signals cannot be seen during fogs and snowstorms.

The audible signals given are the sounding of a siren indicating " Stop " and the ringing of a bell, indicating " Proceed."

The point at which the audible signals are given is usually about 400 yards before the Distant signal is reached. Where, however, the Distant signal is a lower arm on a " Stop " signal, the audible signals are given just as the " Stop " signal is passed.

The apparatus fixed on the permanent way for operating the audible signals on the train is a ramp about 40 ft. long, which is fixed between the running rails, and is made up of a steel T-bar mounted on a baulk of timber. The ramp at its highest point is 4 in. above rail level

A telegraph wire connects the ramp with a switch in the signal box. This switch is attached to the lever controlling the Distant signal, so that when the lever is placed

in the "proceed" position, an electric battery is connected to the ramp, and so that when the lever is placed so as to put the signal in the "Stop" position, the battery is disconnected from the ramp. The ramp is, therefore, electrified when the Distant signal is at "Proceed." When the Distant signal is at "Stop" the ramp is electrically "dead," as is also the case in the event of the battery failing, or in the event of the telegraph wire breaking.

The apparatus on the engine comprises a contact shoe; an electrically controlled brake valve and siren combined, and an electric bell.

The contact shoe is fixed in the centre line of the engine, and projects to within $2\frac{1}{2}$ in. above rail level, in which position it is held by gravity assisted by a powerful spring. It is capable of being raised vertically, and being in line with the ramp it will be seen that it is lifted $1\frac{1}{2}$ in. whenever a ramp is passed over. This lift of $1\frac{1}{2}$ in. is utilized for effectively opening a switch attached to the contact shoe. The switch is connected with the electrically controlled brake valve and siren in such a way that whenever it is opened it results, except as hereafter described, in air being admitted through the siren and the brake valve to the train pipe, sounding the siren and applying the brakes on the train. This is what, in fact, happens when a train passes over an unelectrified ramp. The driver, by acknowledging the audible "Stop" warning given by the siren can stop the siren sounding and stop the application of the brakes. This he does by raising a handle provided for the purpose.

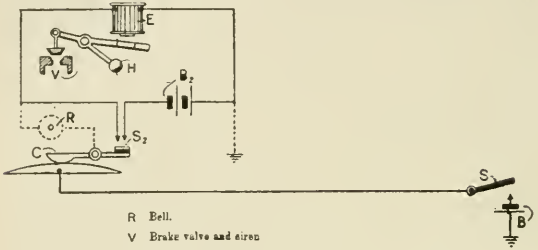
Should the ramp be electrified (through the signalman having placed in the "Proceed" position the lever controlling the Distant signal) when the train passes over it, the brake valve is not released, but the bell on the engine rings instead. The contact shoe is lifted as before, but the current is picked up from the electrified ramp, the effect of which is to cut out, or render inoperative, the switch attached to the contact shoe, so that although the switch is opened, it does not release the valve admitting air through the siren to the train pipe.

In the event of a failure to pick up the electric current when a ramp is passed over, the effect on the engine apparatus is the same as though the ramp were not electrified; that is, the valve admitting air through the siren to the train pipe is opened, and the brakes applied on the train as though a "Stop" indication had been given, thus ensuring that any failure of the electrical apparatus shall produce the "Danger" indications irrespective of the position of the signals.

RAMP AND ENGINE CIRCUITS.

Fig. 3.

CONTACT SHOE ON UNELECTRIFIED RAMP, "STOP" SIGNAL BEING GIVEN.



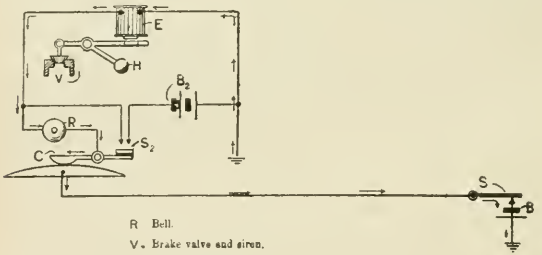
R Bell.
V Brake valve and siren
C Contact shoe.
S Switch (in signal box).
S_2 Switch (attached to contact shoe).
B Battery (line).
B_2 Battery (engine).
E Electro-magnet controlling brake valve and siren.
H Restoring handle.

NOTE.—Switch S_2 open; electro-magnet E de-energised brake valve and siren V open. Handle H used to restore brake valve and siren closed when switch S_2 returns to normal. Line switch S open battery B disconnected from ramp wire.

RAMP AND ENGINE CIRCUITS

Fig. 4

CONTACT SHOE ON ELECTRIFIED RAMP, "PROCEED" SIGNAL BEING GIVEN.

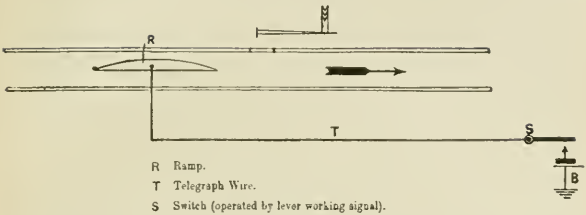


R Bell.
V Brake valve and siren.
C Contact shoe.
S Switch (in signal box)
S_2 Switch (attached to contact shoe).
B Battery (line).
B_2 Battery (engine)
E Electro-magnet controlling brake valve and siren.
H Restoring handle.

NOTE.—Local circuit broken as in Fig 3; line circuit complete as shown by arrows; bell ringing, and electro-magnet maintained energised by line current from battery B

LINE CIRCUIT.

Fig 1.



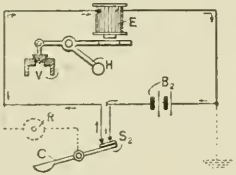
R Ramp.
T Telegraph Wire.
S Switch (operated by lever working signal).
B Battery.

Note.—Battery connected to Ramp only when signal is in "Proceed" position.

LOCAL ENGINE CIRCUIT.

Fig. 2.

NORMAL.



R Bell.
E Electro-magnet controlling brake valve and siren.
V Brake valve and siren.
C Contact shoe.
S_1 Switch attached to contact shoe.
B_2 Battery (engine).
H Restoring handle

Note.—Local circuit closed, electro-magnet energised brake valve and siren closed.

RAVEN'S CAB SIGNALLING APPARATUS.

CABIN EQUIPMENT.—With the adoption of this apparatus there is no departure from the general equipment of a signal cabin or method of operating same. There are additions which cab signalling makes necessary for indicating in the engine cab the conditions of the road to be traversed as the outdoor semaphore signals indicate.

The current collected by the shoe is distributed from the cabin over the bars B, C, D, and E^1 or E^2 corresponding to whichever road may be set. This is decided by the pulling over of the levers that apply to the particular road to be traversed. The circuit being completed by contacts 'p' and 'q' or 'r' and 's', which are made when the corresponding levers are pulled.

When the route to be traversed is decided upon the signalman pulls the levers corresponding to that route. For example, we suppose No. 1 road is clear; he then pulls levers 'H^1' and 'A^1' This, besides lowering the outdoor semaphore arms, transmits a current from battery 'w^1' through contacts 'p' and 'q,' to bars B, C, D and E.

Should, however, any emergency arise or in the first instance the road be not clear the signalman puts 'A^1' to Danger. In this case 'H^1' only being pulled does not energize any of the bars, but the signalman can, by tapping switch 'T^1', momentarily energize the bars. This has the effect of lowering and raising the small semaphore arm and deflecting the pointer of Route Indicator in the engine cab from the centre to No. 1 position. This calls the driver's attention and intimates to him a caution signal.

By the galvanometers 'U,' 'U^1', 'U^2' in the cabin, the signalman can ascertain that the current is being transmitted to the bars, the circuit being completed through resistances 'V,' 'V^1,' 'V^2.' These resistances in no way interfere with signals received on the engine, but form a high resistance shunt on the engine circuit when the brushes are on an energized bar.

ENGINE EQUIPMENT.—Semaphore arm is actuated by armature 'a.'

Route indicator has two armatures, 'b' a non-polarized, and 'c,' a polarized cylindrical one. The latter carries a slotted sector 'd' in which rides a locking pin 'e.' This pin is lifted when armature 'a' of semaphore coils is dropped through the medium of rod 'f' and unlocks slotted sector 'd.' The pointer when released takes up a central position until the next indication is received.

Shoe 'g' is lifted when passing over any of the bars. This opening switch 'h,' thus breaking down closed circuit of semaphore coils which allowing armature 'a' to drop raises small semaphore arm to Danger; this, besides

releasing route indicator pointer, opens contacts 'j' and closes contacts 'k.' the latter completing a circuit through the bell, which commences to ring immediately the shoe has passed off the bar, when the switch 'h' is again closed. This indication continues until the next is received. If the driver chooses to stop the bell ringing he can by pressing switch 'l.' Should the conditions be unaltered on arrival at bar B, the circuit of semaphore coils will again be broken down and the bell will re-commence ringing after the bar has been passed.

Should the line signals be lowered, the bars B, C, D, E^1 or E^2 will be energized. This current, being picked up by the brushes 'm' and 'm^1' of the shoe, operates route indicator pointer to No. 1 or No. 2 for whichever road is set also non-polarized armature 'b', which closes contacts 'n,' thus re-establishing circuit of semaphore coils.

Conclusion.—In the foregoing description reference has only been made to a two-way diverging junction, as shown in Fig. 2. The ruling conditions are applicable to a three-way or four-way junction, the only difference being that bars B, C, and D are duplicated, also line wire, etc., as in Fig. 1.

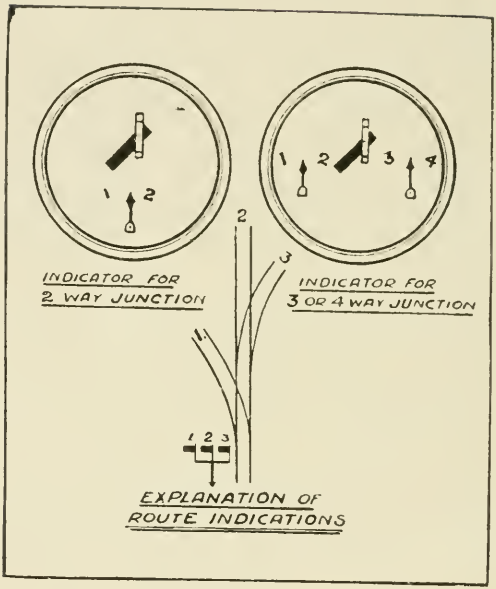


Fig. 1.

RAVEN'S CAB SIGNALLING APPARATUS.

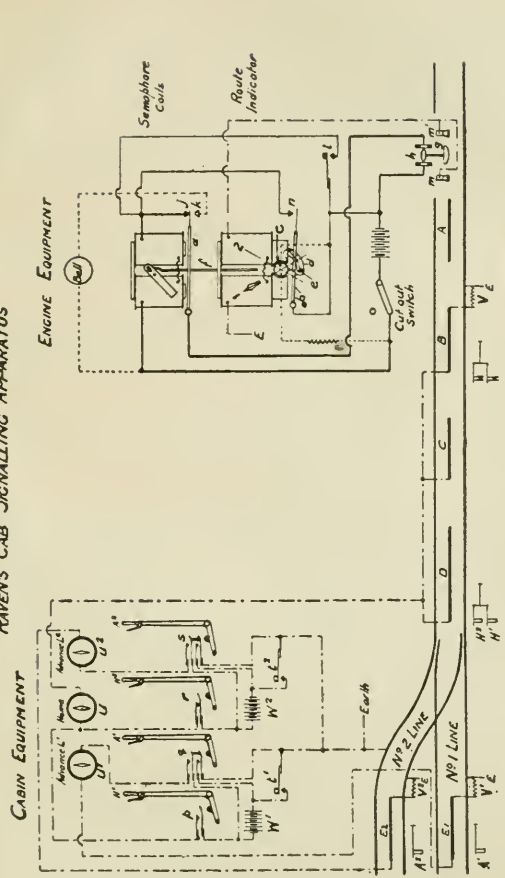

Schematic Diagram of
Raven's Cab Signalling Apparatus
Cabin Equipment
Engine Equipment
Semaphore Coils
Route Indicator
Cut out Switch
Earth
No 2 Line
No 1 Line

Fig. 2.

TYER'S AUTOMATIC TRAIN CONTROL SYSTEM.

This arrangement provides for the positive control over the movements of a second train entering any section of railroad so protected, and is arranged to indicate automatically whether the device is in working order. Any given length of railroad is divided into insulated block sections in the usual manner, and by means of suitable relays an automatic trip, or train stop, is set in operation by a second train entering a protected portion of the road, the stop engaging a sealed glass tube, which, projecting from the engine, forms part of the vacuum brake system of the train.

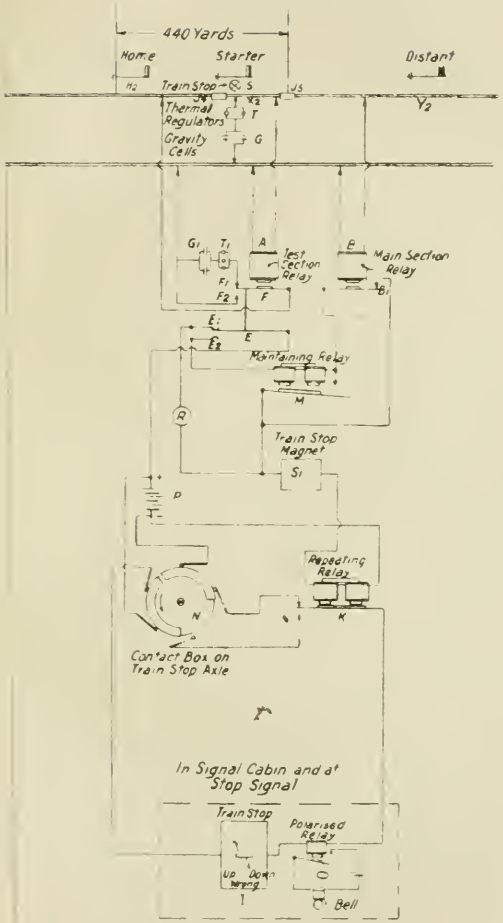
The drawing shows diagrammatically the arrangement of the various electrical appliances on three consecutive sections of the line, all the parts being repeated and in their normal positions.

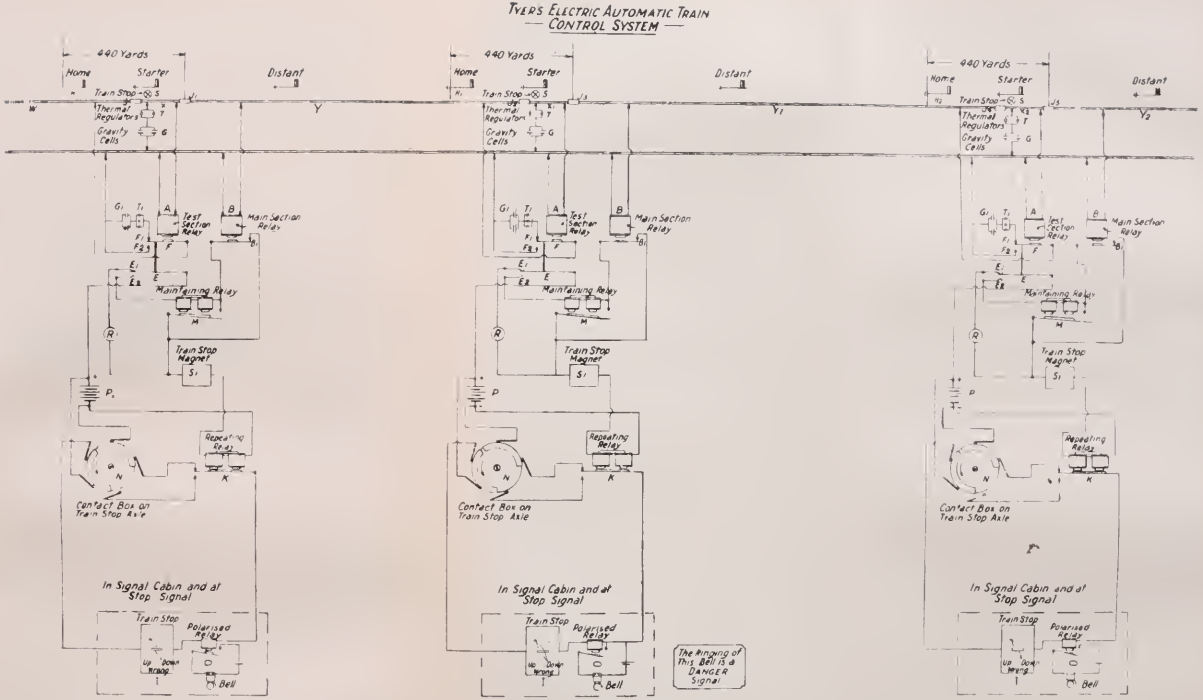
The trip or stop device can be fixed near the home, starting or distant signal, and is normally held in an inoperative position, remaining in this position until a second train comes within the protected portion occupied by a preceding train.

The short length of insulated track X, X1, X2, are known as "test portions," and the length Y, Y1, Y2, as "main portions."

A train entering the test portion X de-energizes relay A, current passing from battery P through lower contacts of A to relay M, which is called a maintaining relay to contact B1 made by main portion relay B, and thence through the coils of train stop magnet S, and repeating relay K back to the battery P; the armature of relay M being attracted forms an alternative circuit for the energizing of Train Stop magnet S. During the passage of a single train S is at all times energized. Should, however, a second train enter X before the preceding train has cleared main portion Y, the maintaining circuit through relay M will be disconnected, and the Train Stop S will be de-energized and rise to its operative position. The Commutator N attached to the train stop S1 is arranged to give a visual signal in the cabin, and if the stop S rises to its operative position the signalman is warned by an audible signal in addition to the visual indicator. Should the Train Stop, through any cause, rise to its operative position without the current through its magnet coils being interrupted, the indicator will show "wrong" and the bell will ring. Similarly, should the current fail without the Train Stop rising, the warning signal will again be given on the indicator and bell.

The apparatus can readily be made to show a red light, or other signal, to the driver of the train in a similar way as the indication is given in the signal cabin.


440 Yards
Home
Starter
Distant
Train Stop
Thermal Regulators
Gravity Cells
Test Section Relay
Main Section Relay
Maintaining Relay
Train Stop Magnet
Repeating Relay
Contact Box on Train Stop Axle
In Signal Cabin and at Stop Signal
Train Stop
Polarised Relay
Up
Down
Bell



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TELEPHONES ON RAILWAYS.

Telephone apparatus consists primarily of a Transmitter to speak into, a Receiver to listen at, some device for calling the attention of the station required to be spoken to, and a bell or other suitable appliance to enable them to call. A diagram of a single telephone circuit is given (Fig. 1).

The carbon granule transmitter is most generally used, and has a resistance at rest of 45 ohms. A sketch (Fig. 2) of the Western Electric Company's solid back transmitter is given.

The principle upon which it works is that the impact of the sound air wave on the diaphragm causes the granules to pack together slightly and so decrease their electrical resistance to a current already flowing through them. When the force of the air wave is exhausted, the diaphragm recovers and the pressure on the granules becomes normal again. As speech is sound, air waves of high frequency, with amplitude, pitch and wave formed of infinite varieties, it will be realized that a transmitter requires to be well made, and carefully adjusted, to give satisfactory results.

Receivers are made in many types. They consist essentially of a diaphragm of iron supported at its edges across the poles of a powerful permanent magnet. The magnet is wound with a coil or coils, which carry the speech current.

The varying speech current causes the permanent magnetism to be varied in strength to the same degree, and it in turn attracts or releases the diaphragm. The rapid movement of the diaphragm sets up sound waves and reproduces those striking the transmitter.

A typical receiver is shown (Fig. 3). For short distance circuits their resistance is 60 ohms. Fig. 4 shows a modern wall set and Fig. 5 a modern pedestal set, both used with C.B. (central battery) working.

When more than two stations are connected by telephone, it is necessary to provide facilities to enable any pair to speak together.

This can be done in a small way up to thirty stations by code, or selective ringing on an omnibus circuit.

Beyond this, resort to an exchange has to be made, and in some cases for fewer than thirty stations a small exchange is preferable.

The system of omnibus circuit working to be adopted depends on whether secrecy is required.

Where it is considered necessary, the circuit could be arranged as shown (Fig. 6).

Another arrangement of selective circuits is worked on the central battery system for signalling. This is used in connection with Train Control systems, where the controller can ring up any station, and they can tell him, but the stations cannot speak to each other.

A diagram of connections is given (Fig. 7), which is self-explanatory.

The procedure is as follows :—

For Controller to Call Station.

The station is selected, and the electrical connections cause the relay at that station to come into action and close the bell circuit. Key A or B is pressed as required, and makes the call. The combination ringing and listening key has to be in the ringing position. After the call is made the combination key is restored to middle position. The station lifts receiver off, and so closes line circuit, and actuates line relay. This lights the red calling lamp. The controller then puts combination key into speaking position, which connects his instrument to the station. It also puts out calling lamp ; closes the engaged lamp relay circuit, and lights white lamp for that station on all the desks. Upon finishing conversation the station hangs up receiver, and controller sets switch into middle position.

The principle on which an exchange works is shown (Fig. 8).

Suppose there are four telephone instruments, A, B, C and D, situated in different parts of a railway. Now A wants to speak to D. On A's instrument there is either a small handle, which he turns, or he simply has to lift the receiver off the hook, when he starts to use it. In either case he calls the attention of an operator sitting in front of the exchange switch-board on to which the wires from his instrument and all the other instruments are connected.

When he turns the handle, a shutter drops down and perhaps rings a bell, and when the receiver only has to be lifted, lamp lights or a white disc is exposed on the exchange board.

The operator does not know to whom A wishes to speak ; so by means of a plug on the end of a flexible wire connection is made with the end of A's wire (this is called the answering plug.) A telephone is attached to the flexible, which enables the operator to ask A for the number required. When this is obtained, the operator connects the " calling plug " to the ends of the wires from D, and presses a small lever, or button, which causes a current to ring a bell at D. When D answers, the operator disconnects her instrument, leaving A and D joined together. When the conversation is finished the attention of the exchange is called by either turning the handle again, or

hanging the receiver up, on the hook. In the first case, it causes a shutter to drop, and in the other a lamp to go out.

The above is the operation of an exchange in its simplest form, but there are many other conditions and circumstances that have to be met, and are dealt with by means of special appliances,.

When the number of " lines " connected to an exchange exceeds the amount which one operator can deal with, it is necessary to arrange the switch-boards so that any operator, should there be more than one, can plug on to any line without leaving the section of the switch-board she is supervising.

This is done by means of the " multiple " system.

The " lines " terminate on the switch-board at a " jack." Every line connected is repeated on every section of the exchange board by a multiple jack (Fig. 9).

It will be realized that an operator must be able to tell whether any line she requires is engaged. This is done by " testing," which involves touching the edge of the required jack with the " answering plug." If the operator hears a " click " in her receiver it shows the line is engaged.

The latest application for railway working is in connection with Train Control systems. By its means information is sent to a central office from points situated in all parts of the control area, and is used to enable trains to be moved and loaded in the most satisfactory manner; staff relieved, and locomotive power efficiently used.

It is essential that communication should be quickly and easily established, and, in consequence, in big control schemes the exchange has been done away with, and the control office operates his own switch-board. Fig. 7 is the diagram of connections for a big control office.

Central battery lamp signalling is used in the Control office, as it is desirable that all the operations should be conducted as quickly as possible. As the different sections of the work are looked after by different men, it is necessary that an engaged lamp should show on each desk when a circuit is occupied. A white lamp shows on each desk when this is so. Likewise a call should show on each desk until taken up.

" Ringing out " to stations is done selectively. " Ringing in " is arranged so that all matters of one sort, such as relief of men, should go direct to one desk. This is obtained by the provision of a special button on the telephone instrument, which calls this desk only. The " ringing in " is by a red lamp signal.

" Ringing out " current is obtained from vibratory generators, worked from accumulators, or dry cells.

The power to work large telephone exchanges, *i.e.*, those with over 100 extension lines, is usually obtained

from a 24-volt accumulator battery, when the central battery system of working is adopted.

This battery provides speaking and exchange signalling current throughout the exchange area.

With small exchanges large Dania dry cells are sufficient for the local speaking ; the ringing out and in being done by hand-driven magnetos.

The outgoing wires from an exchange or control office are usually contained in air space paper-insulated cables.

These cables consist of single hard-drawn copper conductors weighing 10, 20 or 40 or more lbs. per mile, wrapped in a ribbon of dry paper. The wires are made up in pairs, which are twisted together. The paper wrapping is coloured. In some cables similar colours are twisted together, a red and white thread being wound round each wire to distinguish it. Full particulars of the usual colour schemes for paper wire cables will be found in the Post Office Telegraph's Technical Instructions XIV. The Post Office colour scheme for switchboard cable is shown in the table.

The pairs are made up in layers to the required number as many as 600 pairs cable having been successfully manufactured.

A convenient size for railway work is 25 pr. 40 lb. cable.

A sheath or tube of lead is formed round the pairs and this forms an air and water-tight covering.

As the insulation of the wires from each other and the lead sheath depends on the dryness of the paper, special precautions must be taken to prevent wet obtaining access to the paper. Pot-heads are used to seal the cable where the outside wires join the cable wires. Fig. 10.

In the early days of telephony an earth return was used between the extension instruments and the exchange, but with C.B. working with constant current on the line, a complete circuit has been adopted.

The C.B. system has also found out the weak places in G.P. covered wires and G.P. cables, and air-space cables have been substituted for them.

The best modern practice in open work on Railways is 32 poles per mile, or 55 yards apart.

Silicon bronze or hard-drawn copper wire 150 lbs. per mile, is used extensively. When passing a factory emitting noxious fumes, wire covered with indestructible insulation is employed.

White or brown china insulators are universally used. Fuse insulators should be fitted in the line where wires pass over, or under, power wires. Pot-head insulators should be used where the open wires terminate at a cable head.

Open wires near power lines should be covered with some good insulating material.

Standard Sizes of Conductors of Underground Telephone Cables.

10	35	No. 23	89·3
Weight Lbs. per statute mile (1760 yds.)	Diameter. Mile.	Nearest S.W.G.	Resistance over statute mile at 60° F. in standard ohms.
10	35	No. 23	89·3
12·5	28	,, 22	71·2
20	36	,, 20	43·1
25	39·5	,, 19 = 40 mils.	35·8
40	50	,, 18 = 48 ,,	22·3
50	66	,, 16 = 84 ,,	12·8
100	79	,, 14 = 80 ,,	8·94
150	97	,, 13 = 92 ,,	5·93
200	112	,, 11 = 116 ,,	4·45

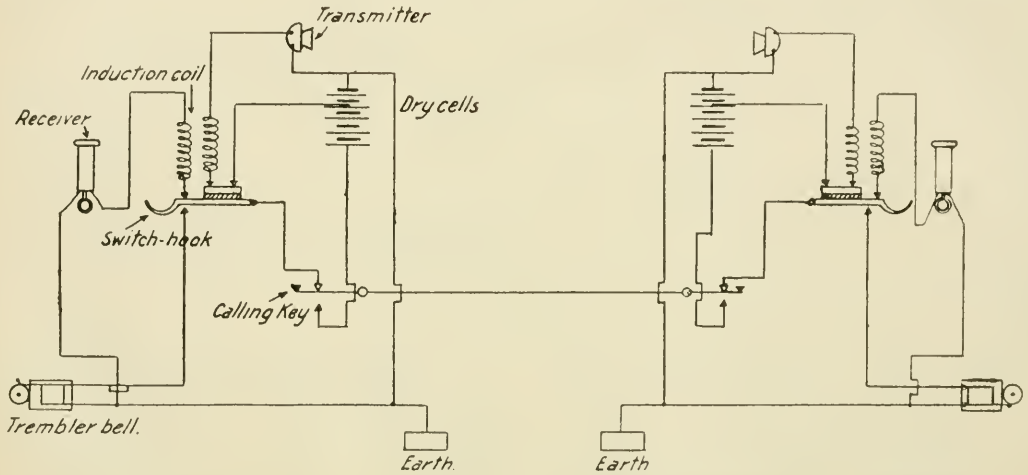
Colour Scheme for Switchboard Cables as used by the British Post Office.

	Pairs. Col. 1	Col. 2		Pairs. Col. 3.	Col. 4
1	Blue	White	22	Red blue	Red
2	Orange	,,	23	,, orange	,,
3	Green	,,	24	,, green	,,
4	Brown	,,	25	,, brown	,,
5	Slate	,,	26	,, slate	,,
6	Blue white	,,	27	,, blue white	,,
7	,, orange	,,	28	,, ,, orange	,,
8	,, green	,,	29	,, ,, green	,,
9	,, brown	,,	30	,, ,, brown	,,
10	,, slate	,,	31	,, ,, slate	,,
11	Orange white	,,	32	,, orange white	,,
12	,, green	,,	33	,, ,, green	,,
13	,, brown	,,	34	,, ,, brown	,,
14	,, slate	,,	35	,, ,, slate	,,
15	Green white	,,	36	,, green white	,,
16	,, brown	,,	37	,, ,, brown	,,
17	,, slate	,,	38	,, ,, slate	,,
18	Brown white	,,	39	,, brown white	,,
19	,, slate	,,	40	,, ,, slate	,,
20	Slate white	,,	41	,, slate white	,,
21	Red	,,	42	White	,,

Cols. 1, 2, 3 and 4	make an	84-wire cable.
,, 1, 2 and 3	,,	63 ,, ,,
,, 1 and 2	,,	42 ,, ,,
,, 1 or col. 3	,,	21 ,, ,,
,, 1 (1 to 11) and Col. 2	,,	22 ,, ,,

A SIMPLE TELEPHONE CIRCUIT:-
Instruments in Speaking Positions

Fig. I



In calling position the Receiver hangs from Switch-hook & depresses one end of it

SOLID-BACK CARBON GRANULE TRANSMITTER.

Western Electric Type

Resistance ordinary type 30 ohms. (approx)

Resistance C.B. type 55 ohms.

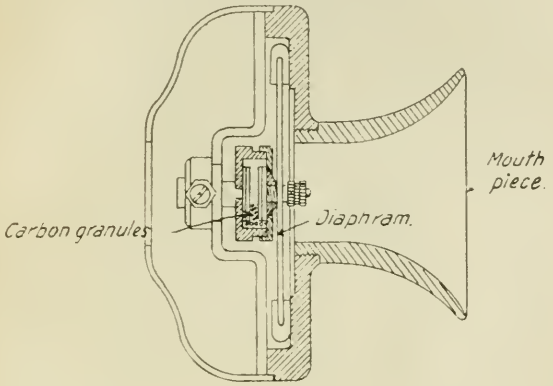


Fig. 2.

KELLOG RECEIVER

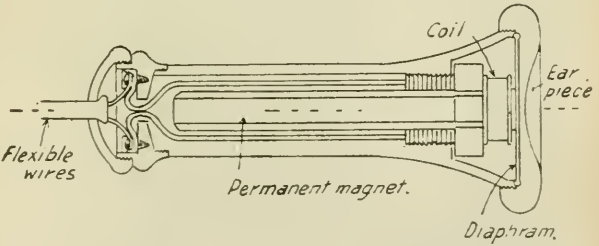


Fig. 3.

Fig. 4.

Fig. 5.

SLOPER & PARSON'S SECRET INTERCOMMUNICATION
TELEPHONE SYSTEM.
Speaking Connections

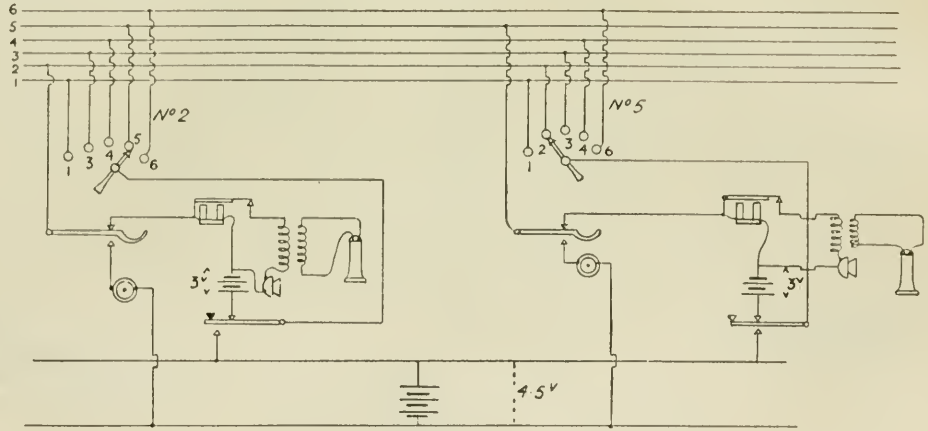
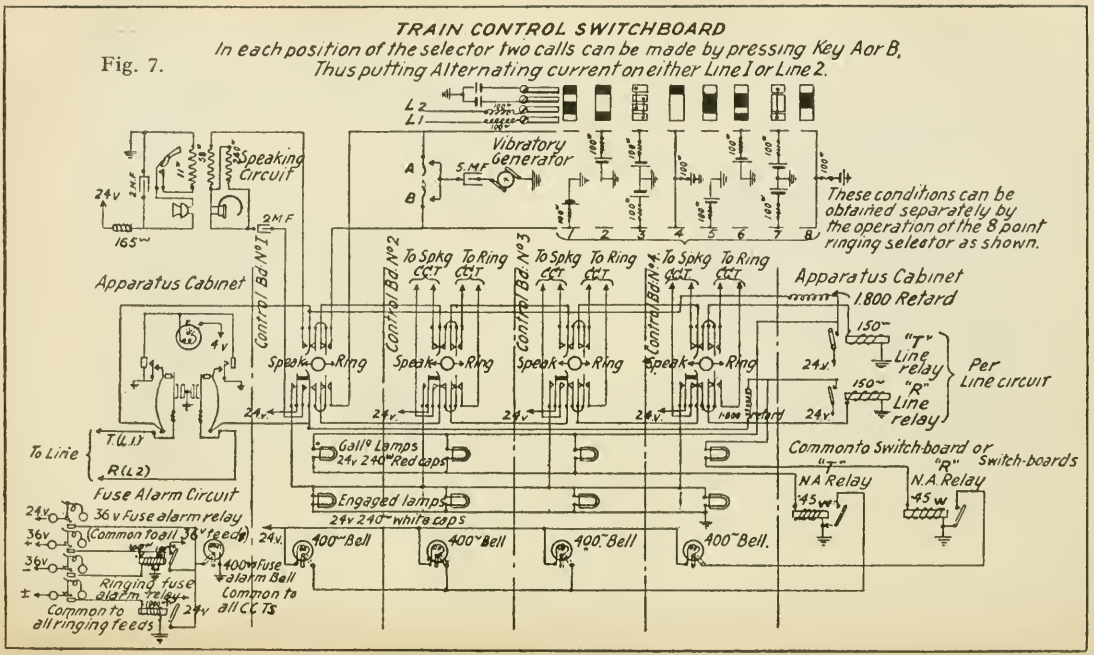


Fig. 6.

Fig. 7.


TRAIN CONTROL SWITCHBOARD
In each position of the selector two calls can be made by pressing Key A or B,
Thus putting Alternating current on either Line 1 or Line 2.
L2
L1
Vibratory Generator
A
B
5 MF
Speaking Circuit
2 MF
165~
24v
These conditions can be obtained separately by the operation of the 8 point ringing selector as shown.
1 2 3 4 5 6 7 8
Apparatus Cabinet
Control Bd. N°1
Control Bd. N°2
Control Bd. N°3
Control Bd. N°4
To Spkg Ckt
To Ring Ckt
Speak
Ring
4v
24v.
Apparatus Cabinet
1800 Retard
150~
"T" Line relay
"R" Line relay
Per Line circuit
To Line
T (L1)
R (L2)
Fuse Alarm Circuit
Gall° Lamps 24v 240~ Red caps
Engaged lamps 24v 240~ white caps
Common to Switch-board or "R" Switch-boards
"T"
N.A. Relay
45 w
36v
36 v Fuse alarm relay
(Common to all 36 v feeds)
Ringing fuse alarm relay
Common to all ringing feeds
400~ Bell
400~ Fuse alarm Bell
Common to all CCTS

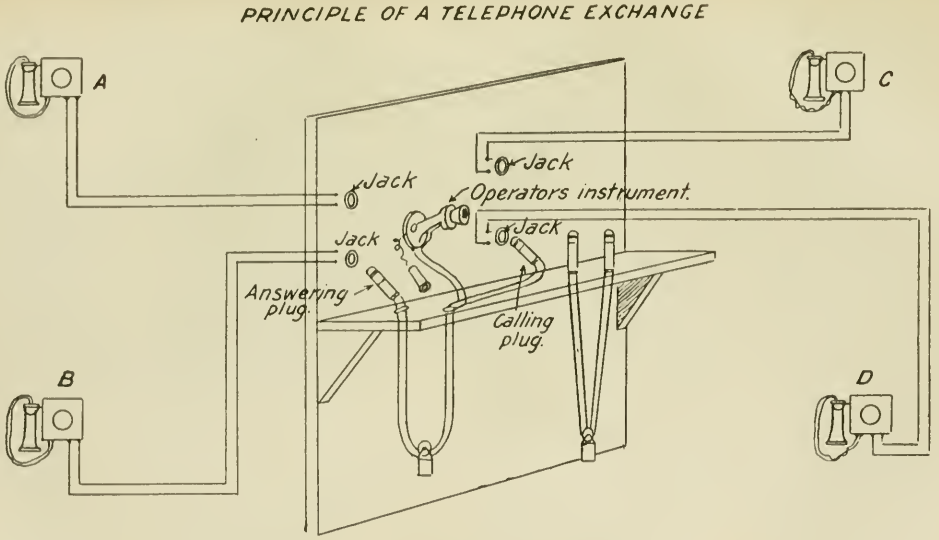

PRINCIPLE OF A TELEPHONE EXCHANGE
A
C
Jack
Jack
Operators instrument.
Jack
Jack
Answering plug.
Calling plug.
B
D

Fig. 8.

TELEPHONE EXCHANGE SWITCH-BOARD.
Principle of the Multiple system.

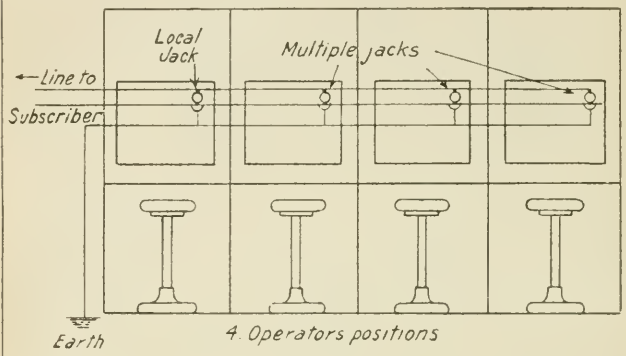


Fig. 9.

INSULATORS FOR OPEN WORK.
– Not to Scale –

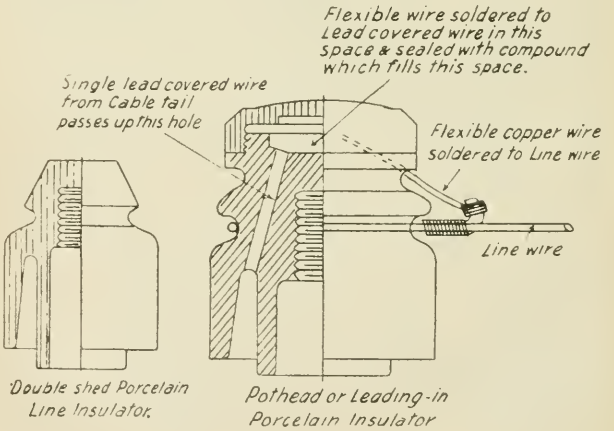

Flexible wire soldered to Lead covered wire in this space & sealed with compound which fills this space.
Single lead covered wire from Cable tail passes up this hole
Flexible copper wire soldered to Line wire
Line wire
Double shed Porcelain Line Insulator.
Pothead or Leading-in Porcelain Insulator

Fig. 10.

TELEGRAPHY.

SINGLE NEEDLE.

For many years past the single needle instrument has been in extensive use on the railways of Great Britain. This is simply because the character of the instrument is so well suited to the work, a typical example being an omnibus circuit linking together a number of signal boxes or small offices. Such a circuit might consist of from ten to twenty single-needle instruments on one wire. During recent years, telephones have been gradually superseding single-needle instruments in this class of work.

The single-needle code is shown in Fig. 2.

In the ordinary form of instrument the signals are sent by two tappers or handles, a depression of the left-hand tapper deflecting the needle to the left, and a depression of the right-hand tapper deflecting it to the right. This lower part of the instrument is known as the commutator.

In the railway form of instrument, a vertical handle rotating about a horizontal axis is substituted for the tappers. A movement of the handle to the right deflects the needle to the left, and *vice versa*.

The Spagnoletti form of needle is widely used, and gives very satisfactory working. According to Professor Ayrton, the best resistance for the coils of omnibus circuit instruments is :—

$$\frac{L}{P}$$

where L = total line resistance in ohms.
P = number of instruments.

In the application of this law, however, there are other considerations as, for example, the number of different coils to be held in stock. Consequently, it is the usual practice to adopt one or two standard resistances, which are found to answer the purpose very well. In some cases one standard of 130 ohms is employed, whilst in others two standards of 300 and 200 ohms are used.

By fixing metal plates emitting different notes on each side of the needle, the signals can be read by sound instead of by sight, thereby increasing the speed of reception, and entailing less fatigue on the operator.

MORSE SYSTEM.

Figs. 1, 3 and 4 give full particulars of the Morse code.

Direct Working.—Fig. 5 illustrates the connections for a simple sounder circuit. The galvanometer is fixed to show whether the working currents are passing properly, and to see whether the line is in order. The sounder

magnet coils are shunted with a coil of high resistance to prevent sparking at the relay contacts when used in the local circuit (Fig. 6).

For use with primary batteries, the coils are usually wound to 20 ohms and shunted with 500 ohms, making the joint resistance 19·2 ohms. With secondary batteries, the coils are wound to 1,000 ohms and shunted with 9,000 ohms, making the joint resistance 900 ohms. A working current of 100 milliampères is required in the first case, and 25 milliampères in the second.

While the line resistance is too high to allow direct sounder working, a polarized relay is employed, which is actuated by the incoming line current, and operates a local circuit (Fig. 6).

Double Current Working.—On circuits where there are several stations, the relay tongue is set in a neutral position, so that the operation of the relay is independent of varying strengths of current from the different stations. The only change in the apparatus is that a different key, known as a double-current key, is employed.

Duplex and Quadruplex.—The name duplex is given to circuits which allow signals to be sent simultaneously in both directions, whilst the quadruplex system provides an equivalent of two duplex sets ; that is, it allows the transmission of four messages, two incoming and two outgoing, simultaneously, on the same wire. Between large railway centres both these types of circuits are much employed, their great utility and economy being self-evident.

LINE WORK.

Line Wire.—The most suitable materials for the line wire are iron and copper, the first because of its strength and cheapness, the second on account of its high conductivity and durability in comparison with ordinary iron. "Armco" Iron Wire, however, is now strongly recommended on account of its good conductivity and purity.

150 lbs. hard-drawn copper having a resistance of 5·85 ohms per mile, is much employed for composite telegraph and telephone circuits and long distance heavily worked telegraph circuits. For short circuits, the block and miscellaneous others 400 lbs. galvanized iron wire having a resistance of 13·32 ohms per mile is used. There are, of course, several other sizes of copper and iron wires in service.

Insulators.—For supporting the line wire, porcelain insulators, screwed on to steel bolts, are employed. The bolt passes through the pole arm or iron bracket, as the case may be, and is secured by a nut and washer.

Poles.—These are made out of quickly-grown larch or fir, and, after being thoroughly seasoned, are creosoted. The size of pole required at any particular point is dependent on (*a*) the number of wires to be carried ; (*b*) the

amount of exposure to the elements, *e.g.*, high wind; (*c*) whether the run of the line is straight, or at an angle. This last point should be carefully noted. The sizes of poles range from 20 ft. to 60 ft. in length, and 8 ins. to 16 ins. in diameter, measured 5 ft. from the butt.

The depth at which a pole is planted depends upon its length, and varies considerably according to the nature of the soil. Heavy poles in made-up ground require special care. No average figure of depth can be quoted.

Pole Arms.—The arm is fitted with a groove cut into the pole, and held in position by a nut and bolt. Arms are made of seasoned oak in the following lengths—24 ins., 33 ins., 48 ins., 57ins. and 72 ins., according to the type of pole, and whether they are for light or heavy lines.

Struts and Stays.—Very considerable strain is put upon a pole at corners or angles of a route, and in order to strengthen it it is the practice to provide either a strut or a stay (Fig. 7). A strut is usually made from an old pole in sound condition bolted to, and braced, to the main pole; a stay is made of stranded galvanized iron wire attached by means of a swivel to an iron rod, which is bolted through a block of wood buried in the earth.

Where these methods are impracticable, "A" and "H" poles are employed. These are shown in Fig. 8.

Pole-roof.—The top of a pole is protected from rotting by having a sheet of galvanized iron known as a pole-roof (from its shape) nailed upon it.

Saddle.—Where only one wire is to be run, the insulator is fixed upon the top of the pole by a bracket known as a saddle (Fig. 9). Where the latter is at an angle of the route, it is supported by a saddle stay.

Underground Wires.—In big centres, the number of overhead wires has grown enormously with a consequent increase in the liability of the poles getting blown down, thereby causing serious dislocation of the services, and considerable damage to life and property. Wires in such positions are also difficult to erect and maintain. To avoid mishap as far as possible, the poles should be always efficiently stayed in all directions.

Hence the employment of underground wires in towns and difficult locations has been rapidly extending for some years. Formerly, the cost was very high, but the extensive use of air space paper insulated cables, in place of gutta-percha covered wires, has greatly reduced the cost of underground work, whilst giving considerably increased electrical efficiency, due to the fact that the specific inductive capacity of the paper insulation and dry air space is so very much less than that of gutta-percha.

The importance of having a low capacity for a high speed on long-distance telegraph lines is well known.

Air space cables require very careful handling, care being taken to avoid twists, sharp bends or damage to the lead cover. The cables are sometimes armoured, which, by considerably increasing the general strength, enables them to be more easily handled.

Those desiring to pursue the subject further should consult :—

"Telegraphy," by Preece and Sievewright.

"Modern Electric Practice," Vol. vi.

"Technical Instructions," issued by the British Post Office.

MORSE CODE.

AFFIXES.

G—	Go on.	
T—	Understand.	
E—	Not understand.	
II—	End of address.	
FI—	Commence figures.	
FF—	Finish figures.	
GQ—	Begin fresh line.	
SN—	Message finished.	
MQ—	Wait.	
KQ—	Call up when ready.	
UQ—	Go to another instrument.	
RR—	Inverted commas	To be given at beginning and end of word to be marked.
LL—	Underlined	
KK—	Parenthesis	
RD—	Message correctly received.	
SQ—	Message to follow.	
MMM—	Horizontal bar of division (dash or hyphen).	
SSS—	Oblique bar of division.	
MM—	Fraction following whole number.	

Fig. I.

SINGLE NEEDLE ALPHABET.

A ↘/	J ↘///	S ⟍⟍⟍
B /⟍⟍⟍	K /⟍/	T /
C /⟍/⟍	L ↘/⟍	U ⟍/
D /⟍	M //	V ⟍⟍/
E ↘	N /⟍	W ↘//
F ⟍/⟍	O ///	X /⟍/
G //⟍	P ↘//⟍	Y /⟍//
H ⟍⟍⟍	Q //⟍/	Z //⟍
I ⟍⟍	R ↘/⟍	

Fig. 2.

The long strokes represent the needle pointing to the right, the short strokes to the left.

MORSE ALPHABET

A ._	J .___	S ...
B _...	K _._	T _
C _._.	L ._..	U .._
D _..	M __	V ..._
E .	N _.	W .__
F .._.	O ___	X _.._
G __.	P .__.	Y _.__
H	Q __._	Z __..
I ..	R ._.	CH ____

Fig. 3.

MORSE CODE

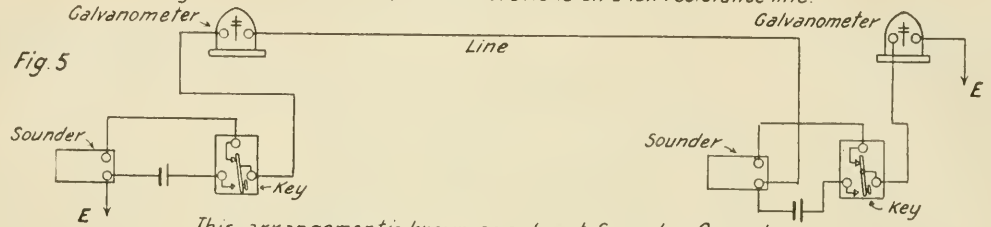
1 .____	. ._._._
2 ..___	, __..__
3 ...__	: ___...
4 ...._	; _._._.
5	? ..__..
6 _....	! _._.__
7 __...	
8 ___..	
9 ____.	
0 _____	

Fig. 4.

MORSE SYSTEM.

Diagram of connections for two stations on a low resistance line.

Fig. 5

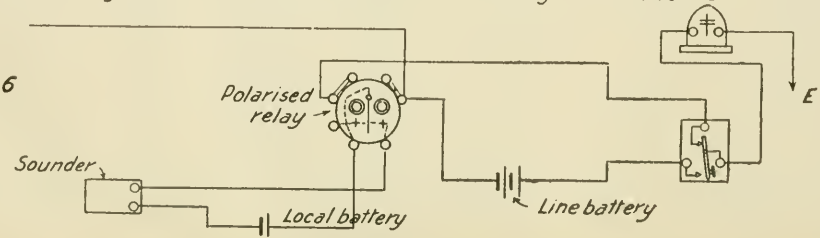


This arrangement is known as a direct Sounder Circuit

MORSE SYSTEM

Diagram of connections for a station with a high resistance line

Fig. 6



This arrangement is termed a single-current sounder set.

METHODS OF STRENGTHENING TELEGRAPH POLES.

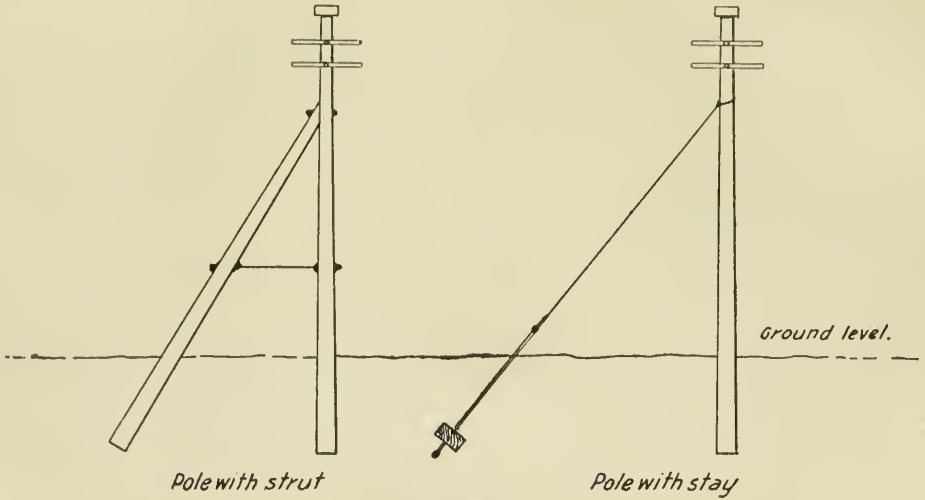


Fig. 7.

TYPES OF TELEGRAPH POLES
for heavy lines.

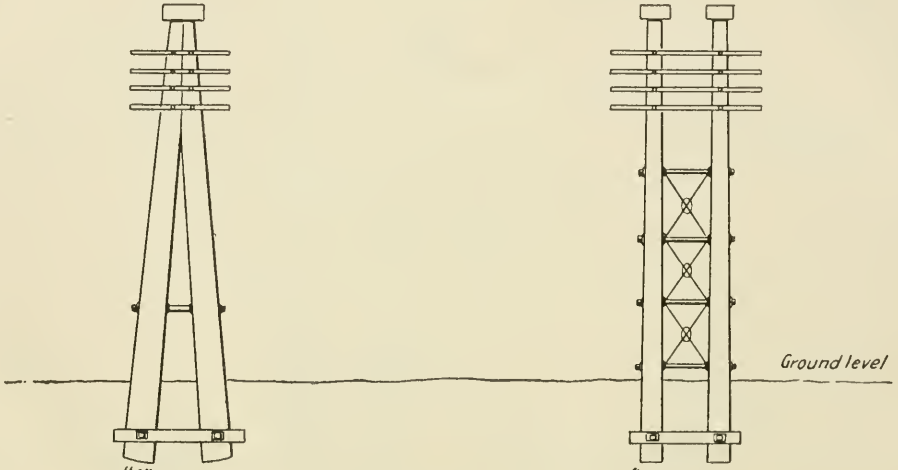
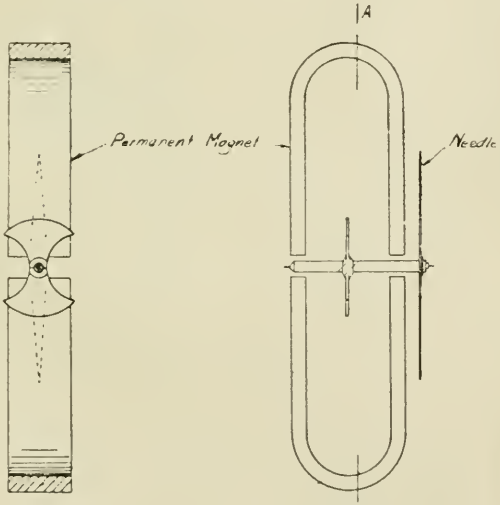


Fig. 8.

SADDLE BRACKET
For Telegraph Pole

Fig. 9.

SPAGNOLETTI NEEDLE



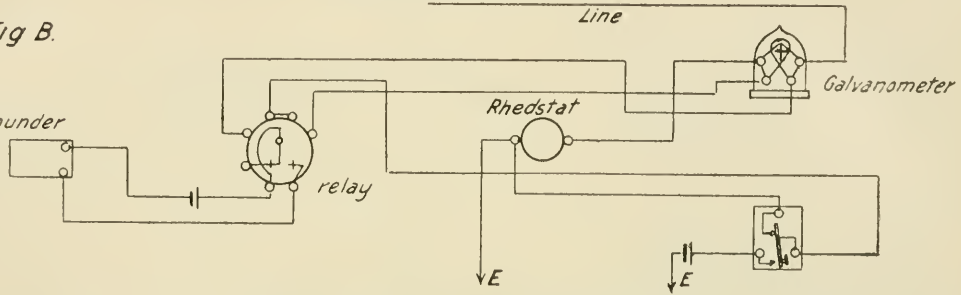
SECTION THRO' A-B

SIDE VIEW

Fig. A.

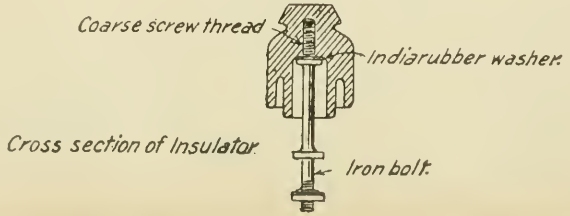
SINGLE CURRENT DUPLEX.
Diagram of connections.

Fig B.



PORCELAIN TELEGRAPH INSULATOR.
Cordeaux Screw Pattern.

Fig. C



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BOARD OF TRADE REGULATIONS FOR RAILWAYS.

Extracts.

Catch points to be provided at junctions of passenger with goods lines or sidings, and interlocked with signals.

Junctions at stations to be formed so as to avoid standing trains on them. All junctions to be formed for double line.

At termini double line shall not end single.

Platforms not less than 6 feet wide for small, and 12 feet for large, stations; ends ramped.

Pillars, etc., not less than 6 feet from edge of platform.

Height of platform above rail to be 3 feet; in no case less than 2 ft. 6 in.

Space between platforms and carriage footboards to be as small as possible.

Viaducts near stations to have efficient parapet.

Footbridges or subways at all important stations.

Staircases or ramps leading to platform to be nowhere narrower than at top. Where crowding is expected, provision must be made for regulating crowd at top. No steps to have tread less than 11 inches or rise less than 7 inches. Landings where height is over 10 feet. Ramps not steeper than 1 in 8. Hand railings for steps and ramps.

No station to be on a steeper gradient than 1 in 260 if avoidable.

Where there is danger from such cause catch sidings to be provided.

Turntables large enough for the longest engines to be provided at termini and junctions, except lines less than 15 miles long, with stations less than 3 miles apart, if Company undertake to stop all trains at all stations. Turntables to be at safe distance from adjacent lines.

Cast-iron not to be used in railway under-bridges except in compression. Breaking weight of cast-iron to be not less than 3 times dead, plus 6 times maximum live load.

In wrought-iron or steel bridges, dead maximum live load shall not produce greater strain per sq. inch than 5 tons in iron, and 6½ tons in steel.

The heaviest engines, etc., to be measure of max. live load.

Viaducts, as far as possible, to be of masonry.

With iron or steel girders rails to be between main girders.

In all cases there shall be a parapet 4 ft. 6 in. above rail level. On important iron, steel or wood viaducts, there shall be timber guard close to, and outside, outer rails.

Cast-iron columns of small diameter not to be used for piers or abutments of high bridges.

Wind pressure of 56 lbs. per sq. ft. to be allowed for

Upper surfaces of wood platforms of bridges and viaducts to be protected from fire.

Joints of rails to be fished.

Chairs on main lines to weigh not less than 40 lbs.; on branch lines or with light traffic not less than 30 lbs. Chairs must be fastened to sleepers, at least partially, by iron spikes or bolts. Where there are no chairs, fastening to sleeper at joints to be by means of fang or through bolts, and such rails to be tied to gauge by steel or iron ties at suitable intervals on curves of 15 chains radius, or less.

Check rail to be fixed on all curves of 10 chains, or less, radius.

Diamond crossing not to be flatter than 1 in 8.

No structure, other than a passenger platform, to be nearer side of carriage than 2′ 4″.

Intervals between adjacent lines of rails to be not less than 6′ for two lines, or lines and sidings, and not less than 9′ 6″ between additional running lines and main lines.

Half, quarter, mile, and gradient posts to be provided.

Tunnels and long viaducts to have refuges for platelayers.

Under-bridges without parapets to have handrails. Viaducts of steel, iron or timber to be easy of inspection.

PARLIAMENTARY REGULATIONS FOR RAILWAYS CROSSING ROADS.

	Turnpike Road.	Public Road.	Occupation Road.
Clear width of underbridge or approach	35′ 0″	25′ 0″	12′ 0″
Clear height of underbridge for a width of 12 feet ..	16′ 0″	—	—
Ditto, for a width of 10 feet ..	—	15′ 0″	—
Ditto, ,, ,, 9 ,, ..	—	—	14′ 0″
Ditto, at springing	12′ 0″	12′ 0″	—
Overbridge, height of parapets	4′ 0″	4′ 0″	4′ 0″
Approaches, Inclination ..	1 in 30	1 in 20	1 in 16
Ditto, Height of fencing	3′ 0″	3′ 0″	3′ 0″

DESIGN AND MANUFACTURE OF PERMANENT WAY MATERIALS, FITTINGS, ETC.

RAILS.

ROLLING.—Ingots, after being reheated to bright redness in the soaking pits, are taken out one at a time and passed on to the cogging mill, by means of a live roller track. Here, after a series of passes through the rolls, it becomes greatly elongated, with a cross section now of 6″ by 6″. It is next skidded laterally to the finishing rolls, where, after passing through the six grooves, it emerges from the last in one length true to the rail section.

CUTTING.—The finished length while still hot is run down a roller track past the circular saw, and a stop about 5 feet beyond the latter is dropped, thus arresting the leading end. The saw is set in motion and by means of a lever is moved at right angles to the rail, thus cutting through it, the "crop" end is run off aside, and a second stop at slightly more than the standard length from the saw is lowered (allowing for contraction of the rail in cooling), the saw is actuated and a rail length cut. In this manner the long length is cut up into rails and the "crops" from each end are returned as scrap to the furnaces. The rails are placed on benches to cool.

STRAIGHTENING.—This operation is done by "eye." The rail to be straightened is laid on the table of the press web vertical; the straightener sights along the head from one end and indicates the "kinks" to another man pointing along it; these are chalk-marked. The rail is then shifted on the bed of the machine until one of these marks is vertically under the oscillating ram, by interposing a gag "on flat" on the rail head; the bend is taken out on the down stroke of the ram. In this way variations are corrected. To press out a side kink the rail is turned web horizontal and gag interposed "on end."

SQUARING AND DRILLING.—The rails are taken to the drilling shed. Here on a bench, exactly at right angles to the machine, the rough sawn ends are milled square. The finished length is not allowed to vary more than 3/16ths of an inch either way from the specified length. The elongated fish-bolt holes are then accurately drilled. Their position must be correct to a 32nd of an inch.

SUITABLE WEIGHT.—This depends chiefly on the maximum axle weight of the locomotives using the track. The average practice is as follows :—

Maximum axle weight.	Weight per yd. new.	Minimum weight per yd. worn.
17-20 tons ..	90-100 lbs. ..	80-85 lbs.
15-17 ,, ..	80- 90 ,, ..	70-75 ,,
13-15 ,, ..	70- 80 ,, ..	60-65 ,,

Wear.—On British Railways, for open country tracks clear of station yards, the average wear is about 2/5ths lb. per yard per annum, 1 to 2 lbs. in busy stations, and manufacturing centres where sulphurous atmosphere has a deleterious effect, 1½ to 3 lbs. in tunnels, according to length and clearness, and 4 to 5 lbs. on electric lines in the open.

Rails frequently have to be removed before being reduced to the minimum weight on account of flange cutting on sharp curves.

Calculated Weight from Worn Section.—When rail weighings cannot conveniently be taken a very near approximation can be obtained from the profile. This is made by inserting a piece of cardboard in the joint (the fish-plates having been removed) and tracing on it very carefully the profile. The actual weight can be now found by multiplying the area of the cross section in square inches by 10·2 lbs.

BRITISH STANDARD SPECIFICATION FOR BULL-HEAD RAILWAY RAILS.

The Recommendations of the Sub-Committee on Railway Rails.

The rails shall show on analysis that in chemical composition they conform to the following limits:—

Carbon	from 0·35 to 0·50 per cent.
Manganese	,, 0·70 ,, 1·00 ,,
Silicon	not to exceed 0·10 ,,
Phosphorus	,, ,, 0·075 ,,
Sulphur	,, ,, 0·08 ,,

The manufacturer shall make and furnish to the representative of the Engineer (or of the purchaser) carbon determinations of each cast.

A complete chemical analysis representing the average of the other elements contained in the steel shall be similarly given for each rolling. Such complete analysis shall be made from drillings taken from the rail or from the tensile test piece or pieces. When the rolling exceeds 200 tons an additional complete analysis shall be made for each 200 tons or part thereof.

Each rail shall be made from an ingot not less than 12 inches square at the smaller end and 14 inches square at the larger end, which must be cogged down into blooms and have sufficient crop then sheared from each to ensure soundness.

All straightening shall be done by pressure and not by hammering.

A rolling margin of ½ per cent. under to ½ per cent. above the calculated weight will be permitted, but the calculated weight only will be paid for.

TABLE OF GENERAL DIMENSIONS AND WEIGHTS OF "B. S." RAILS.

No. of "B.S." Sections and Nominal Weight in lbs. per yard.	Height of Rail.	Width of Head.	Calculated Weight of Rail.
	Inches.	Inches.	Lbs. per yard.
60	$4\frac{3}{4}$	$2\frac{5}{16}$	59·79
65	$4\frac{7}{8}$	$2\frac{3}{8}$	64·58
70	5	$2\frac{7}{16}$	70·13
75	$5\frac{1}{8}$	$2\frac{1}{2}$	74·56
80	$5\frac{3}{8}$	$2\frac{9}{16}$	79·49
85	$5\frac{15}{32}$	$2\frac{11}{16}$	84·88
90	$5\frac{35}{64}$	$2\frac{1}{4}$	89·77
95	$5\frac{23}{32}$	$2\frac{3}{4}$	94·59
100	$5\frac{29}{32}$	$2\frac{1}{4}$	99·84

The whole of the rails shall be of uniform section throughout, true to templates, perfectly sound and straight, and free from splits, cracks, burrs and defects of every kind.

The Committee recommend the adoption of the following as the normal lengths of rails, *viz.*:—30 feet, 36 feet, 45 feet or 60 feet.

The rails shall be the specified length at a temperature of 60° Fahr. No rail will be accepted which is more than three-sixteenths of an inch (3/16″) above or below the length specified, whether for straight or curved line.

From each cast one rail shall be selected by the representative of the Engineer (or the Purchaser). From this a piece 5 feet long shall be cut which shall be placed in a horizontal position with the bull-head uppermost upon two iron or steel supports resting on a solid foundation, and placed so that their centres are 3 feet 6 inches apart, the upper surfaces of the supports being curved to a radius of 3 inches.

The test shall comprise two blows delivered mid-way between the bearings from a falling iron weight of 2,240 lbs., the striking face of which shall be rounded to a radius of not more than 5 inches.

The height of drop for the various sections of rails shall be as tabulated on the next page. The blows must be sustained without fracture and the rail must show a deflection between the limits given.

FALLING WEIGHT TEST.

No. of "B.S." Section and Nominal Weight of Rails. per yard in lbs.	1st Blow			2nd Blow.		
		Deflection.			Deflection.	
	Drop.	From	To	Drop	From	To
	Feet.	Ins.	Ins.	Feet.	Ins.	Ins
60	5	1	1 5/16	10	3	3 3/4
65	5	1	1 1/4	12	3	3 3/4
70	6	1	1 5/16	12	3	3 3/4
75	6	1	1 5/16	12	3	3 3/4
80	6	7/8	1 3/16	15	3	4
85	6	7/8	1 3/16	15	3	4
90	7	7/8	1 1/4	20	3	4 1/4
95	7	7/8	1 3/16	20	3	4 1/4
100	7	7/8	1 3/16	20	3	4 1/4

Should the length cut from the selected rail fail to comply with the test specified for its weight, two other rails from the same cast will be selected and similar lengths cut and tested, and the acceptance, or rejection, of the cast will be decided by the result of the three tests, so that if two of the rails selected fail to comply with the test the entire cast will be rejected.

TENSILE TEST.

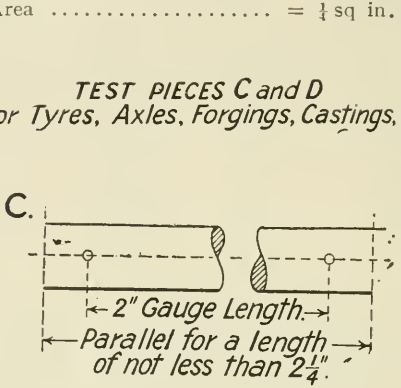
From each 100 tons of rails the manufacturer shall (if required by the representative of the Engineer or of the Purchaser) cut a test piece from any rail selected as a sample rail; such test piece to be stamped to correspond with the sample rail. It shall then be placed in a testing machine of approved pattern, and shall have an ultimate tensile strength of not less than 40 tons per square inch, nor more than 48 tons per square inch, with an elongation of not less than 15 per cent. upon the standard test pieces C or D (see sketches on page 206).

Should the test pieces fail to fulfil these conditions, the representative of the Engineer (or of the Purchaser) may require the manufacturer to test two other rails from the same cast in the same manner, and the acceptance, or rejection, of the cast shall be decided by the result of the three tests, so that if two of the rails selected fail to comply with the test, the entire cast will be rejected.

TEST PIECES C. and D.
for Tyres, Axles, Forgings, Castings, etc

C.

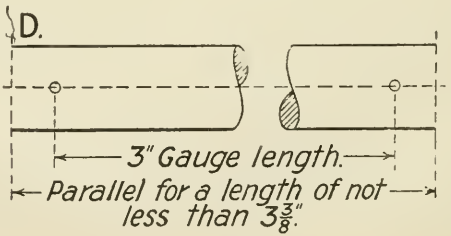
Diameter ..... = ·564 in.
Area ..... = ¼ sq in.



D.

Diameter ..... = ·798 in.
Area ..... = ½ sq. in.

The gauge length and the parallel portion to be as shown. The form of the ends to be as required in order to suit the various methods employed for gripping the test piece.



SLEEPERS.

Wooden.—The timber most commonly used for sleepers is Baltic (pinus sylvestris), though jarrah, Scotch fir, and larch are used to some extent. The timber is specified to be free from large and dead knots, shakes, wavy edges and twisted grain.

Inspection.—The imported timber is delivered to the timber contractor's yard in 9 ft. hewn logs 10″ by 10″. These are halved, and in cases where the railway companies have their own sleeper depôts, are delivered by the contractor in 9 ft. by 10″ by 5″ scantling; a representative of the railway inspects the delivery, and rejects those which do not comply with the specification, the thickness when questionbale being checked with a 5″ jaw gauge.

Seasoning.—The accepted sleepers are put into stacks and left to dry for a period of not less than six months.

Adzing and Boring.—To obtain a good seating for the chair on the hewn side, the dried sleepers are machine-adzed parallel to the sawn side, thus providing a constant thickness at the seatings. The bolt holes are also bored at the same machine. The augers of this machine can be accurately adjusted to the correct centres, and the holes bored truly vertical.

Preservation.—Baltic fir is invariably creosoted to prolong its life. This is always done after boring, to ensure all surfaces being treated. The process is as follows:—Cylinders of 300 to 400 sleepers capacity, erected over the creosote tanks, are charged with sleepers, and the end door carefully sealed. The air is then withdrawn by a vacuum pump, after which the oil valve is opened. The creosote previously heated to about 120°F. to increase its mobility, rushes into the cylinder, but the initial absorption is quite insufficient, and a force pump has to be set working, a pressure of 100 lbs. per square inch being often approached before impregnation to the desired quantity is attained. The usual quantity per sleeper is 3-3½ galls., or 31½-37 lbs. The simplest method of measuring the absorption is by taking dippings in the ground tank with a steel rule, the capacity of the tank per inch of depth being known, the quantity taken out can be gauged from the differences of level of the oil in the tank. The process of creosoting takes from 1 to 1½ hours, according to the degree of the porosity.

"Chairing" (Machine).—The chairs are laid on simply, the bolts inserted in the holes and given a couple of turns. The sleeper goes forward to the machine, and is placed in position; rams descend in the jaws and press the chairs firmly on their seating. Whilst thus held spanners are lowered and bolts quickly screwed up. The gauge between the inside jaws is then tested for accuracy.

RAIL ROLLING

Fig. 1. Development of Section at "Finishing Rolls"

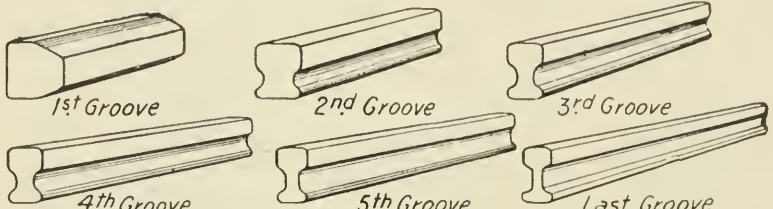
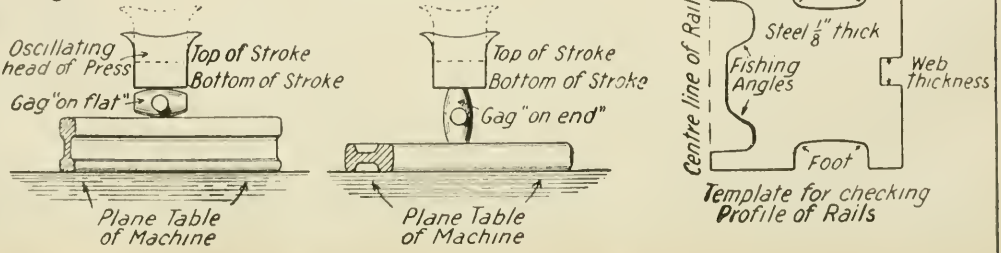
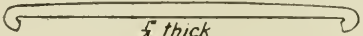


Fig. 2. STRAIGHTENING RAILS



STEEL JAW GAUGE

For checking accuracy of Chairing.



Gauge used when inspecting sleepers, to test their thickness

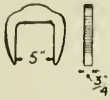


Fig. 3.

CHAIRING SLEEPERS (Hand).

Sketch shewing Framed Gauge

Fig 4.

LONGITUDINAL TIMBERS

Arrangement on Bridges with Rail Bearers.

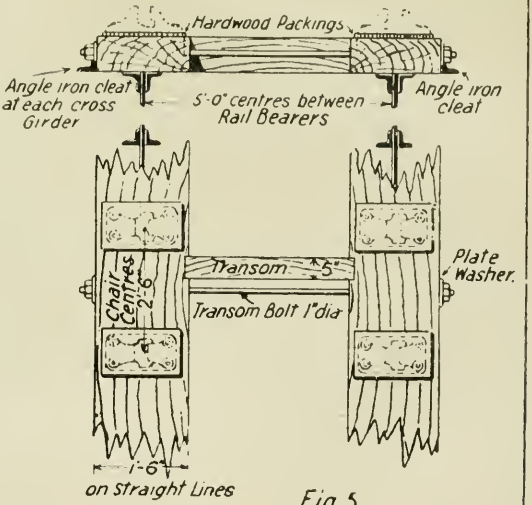


Fig 5

Chairing (Hand).—This is usually done on the ground. One chair is placed on the sleeper at a fixed distance from the end and centred. Men provided with augers bore the holes and screw the bolts up tightly in them. A framed gauge is then placed with one end in the jaw of the fixed chair, whilst a loose chair is put into position at the other end on the sleeper. (See Fig. 4.) The gauge is wedged down tightly in the jaws and the remaining holes for the loose chair bored, the bolts being screwed up before the gauge is removed. Unless the holes are driven vertically, any subsequent tightening of the bolts will "draw" the chairs, with conesquent variation of gauge. Hence it is obvious that machine chairing is not only more expeditious but also more accurate than hand-chairing.

Crossing Timbers.—These are sawn both sides, hence adzing is unnecessary; also the position of the chairs being variable, they are sent out unbored. These timbers are generally 6″ deep, in two widths—12″ and 14″; and of various lengths, from 9 ft. to about 45 ft. They are inspected and creosoted as described above for sleepers. The quantity of creosote per 50 cubic feet of timber is 30-40 galls.

Longitudinals.—On many bridges provided with rail bearers between the cross girders, longitudinal timbers are laid. They are often of Oregon Pine creosoted, or Jarrah, a hard wood not requiring a preservative. The dimensions are usually 18″ by 7″ and lengths up to 35 ft. or 40 ft. In the case of the pine, hard-wood packings laid grain across the timber are interposed under the chairs to prevent cutting in. The timbers are maintained to gauge by transom of the same timber, let in between, and tied by a through transom bolt. The whole is maintained in position on the bridge by angle iron cleats, which fit against the timbers, and are fixed on top of the cross girders. The standard type of cross sleeper road in ballast is always to be preferred, as it is far easier to pack and keep to true alignment; especially where cant is being run up on the bridge.

Steel.—These are generally of the trough form, and though very much in evidence abroad do not find much favour here. They are subject to deformation under heavy loads and in packing, this affecting the gauge; also the fastenings soon work loose and rattle. The running where there are steel sleepers is distinctly "harsher" than on wooden.

Ferro-Concrete.—There is a difficulty in providing a reliable fastening for the chairs. The usual practice is to insert wooden plugs bored to take the bolts, but it is found that the former shrink and become loose. In packing it is found that the edges very quickly chip away.

Life.—The life of a Baltic sleeper under ordinary conditions is from fifteen to twenty years, the longer period applying to the lighter lines and branches.

CHAIR DESIGN.

The two principal functions of a chair in the "bull-head" type of road are (1) to spread the wheel weight over a sufficient area of the sleeper, and (2) in conjunction with the key, to keep the gauge.

There are many minor points of difference in the chairs of the principal railway companies, but they are nearly all of the general form which may be described as a base and two jaws.

The area of the base must be such that the chair will not be easily forced into the timber. The shape of the base should ensure a fairly even pressure over the surfaces in contact; and the thickness sufficient to prevent fracture under any condition of loading.

On the upper surface the rail "seat" is formed to agree in shape with the rail base, when the rail is at the desired cant or inward inclination (1 in 20—1 in 24) to suit the conicity of the wheel tyres.

The two jaws should be shaped so that when the rail is in correct position its web is pressed against the inner jaw by the action of the driven key between the web and the outer jaw. They must be strong enough to resist all lateral thrusts, and stresses due to key driving.

The chair as a whole should be designed so that the pattern can be easily withdrawn from the mould.

To secure true gauge, the inclination of the rail seat and jaw must be accurate.

Weight and Area.—

Weight of rail.	Weight of chair.	Area of base of chair.
95-100 lbs. per yd.	50-55 lbs.	110-115 sq. ins.
85-95 ,, ,,	45-50 ,,	100-110 ,,

Specification.—Chairs are usually of cast-iron; to be clean; free from air bubbles or honeycombs, and of smooth surface.

Moulding.—They are either machine or hand moulded, the patterns being themselves of cast-iron on account of so much repetition work. The rail jaw being in the form of a clip over the bottom member, slips are provided in the patterns to enable them to be withdrawn. The pattern is placed in the bottom box jaws up, and the sand rammed well around; the box is then inverted and the pattern with slips withdrawn.

The top box is then prepared and forms the base, carrying a curved projection if the chair is hollowed. It is then placed on the bottom box with pouring hole and vent, after which the molten metal is run in, and the casting left to cool.

CLEANING.—The castings are placed in a drum along with "shot" (small scrap). The drum is revolved by a belt drive, and the contents well rattled. After the removal of the castings from the drum, the holes are cleared by hammering drifts through them.

TEST.—Two chairs are taken at random from a stack and placed on a base plate carrying plugs at the bolt-hole centres. With plugs in the holes of the chairs, short rail lengths are keyed up and the gauge checked with a template, also the inclination of the two rails. This test is applied from time to time to ensure accuracy in the castings.

KEYS.

DESIGN.—They are almost invariably inserted on the outside of the chairs, forming an efficient cushion, and they minimize noise in running. They should fit up truly to the web and fishing angles. Means should be adopted to retain them in the jaws, by curving the key jaw to produce wedging, or grooving the jaw suitably to increase friction, or by tapering the key.

STEEL.—Coiled steel keys are liable to deteriorate and lose their elasticity in wear. Steel wedge devices are unsatisfactory, owing to their becoming disengaged by vibration. The friction between metal and metal being much less than metal and wood, the latter are more reliable.

MANUFACTURE.—The most common material for keys is well-seasoned oak, specially compressed to counteract shrinkage. The dried logs are cross cut to the required length, and divided up into key blocks of rectangular section, allowance being made for the machining which follows.

These blocks are planed to the proper section, a margin being allowed if compression is to follow.

In cases where they are compressed, it is done by immersing the blocks in plumbago as a lubricant, and they are forced by hydraulic rams into iron taper moulds of the final section. The moulds are next thrown into a cylinder, and steamed for about an hour, and when they have cooled down are forced back again out of the moulds

INSPECTION.—The keys are tested for accuracy by means of steel templates, length, thickness and width being checked. (See Fig. 7.)

FISHPLATES.

DESIGN.—The suspended form of joint is generally preferred. Experience shows that in the case of a

supported joint severe hammering takes place, due to want of elasticity, causing burring over of the rail ends, and consequent failure of the joint. In the former type the sleeper spacing is reduced, the neighbouring chairs being brought up as close as the fishplates will allow. The span, *i.e.*, the distance between chair centres, for 1′ 6″ fishplates is about 2′ 1″. Expansion of the rails is provided for first, by elongating the holes in the rails; secondly, by giving clearance between bolt and hole in fishplate; the two combined permitting sufficient travel for the rails to butt dead at the maximum, and to open out freely for the minimum temperature. The maximum gap to be allowed depends on the length of rails adopted. In practice it is usual when laying the rails to vary the gap to suit the temperature at the time. Small angle iron plates are inserted in the joints, their thickness depending on that prescribed for the season of the year. For 45 ft. rails they would vary from $\frac{1}{8}$″ to $\frac{7}{16}$″ in steps of $\frac{1}{32}$″.

The fishplates have their top and bottom edges accurately sloped to fit the fishing angles of the rails to be connected. They do not fit close up to the web, a clearance of about $\frac{1}{4}$″ being allowed for taking up wear. In most cases four bolts are provided, the holes in the plates are "quarter square," also the necks of the bolts, to prevent the latter turning when the nuts are being screwed up.

The plates in section are slightly arched in form; hence when bolts are tightly screwed up they are always in tension; especially when the joint is deflected; consequently, it is not usual to apply any locking device for the nuts.

Manufacture.—The steel ingots are cogged down and cut into blooms, these being passed through the finishing rolls, and emerging as fish bars true to section.

While still hot the bars go to the circular saw, there, after the crop ends have been taken off, to be cut up into equal fishplate lengths.

The plates are next punched—also while hot, the four holes simultaneously. No margin is allowed for error in position of the holes, but their diameter must be within a 1/32″ error. They are then filed to take off all burrs; straightened by pressure, and finally dipped into boiled linseed oil.

Inspection.—By means of a combined template gauge the fishing angle, thickness across centre line, profiles of outside and inside are carefully checked, and the bolt hole centres by another gauge.

Practical Tests.—These are to bend a plate when cold around a bar 3″ or 4″ diameter to a right angle; and to double a plate; there must not be any sign of fracture when thus bent.

FISH-PLATES.

Extracts from the British Standard Specification.

The fish-plate shall show on analysis that in chemical composition they conform to the following limits :—

Carbon	.. .. ..	from 0·20 to 0·30	per cent.
Manganese	.. .. ..	,, 0·50 ,, 0·75	,,
Silicon	.. .. ..	not to exceed 0·06	,,
Phosphorus	.. .. ..	,, 0·06	,,
Sulphur	.. .. ..	,, 0·06	,,

A test-piece shall be cut from any fish-plate selected as a sample, and shall have an ultimate tensile strength of not less than 30 tons per square inch, nor more than 35 tons per square inch, with an elongation of not less than 20 per cent. upon the standard test pieces C or D (see page 177).

Fish-plates shall be bent over the flat surface round a bar 3 inches in diameter, with one of the bolt holes situated at the centre of the bend, until the two ends become at right angles to one another. They must also be capable of being similarly bent round a bar 3 inches in diameter, the bend taking place between the bolt holes, until the two ends become parallel to one another,

BRITISH STANDARD FISH-PLATES FOR BULL HEAD RAILS. TABLE I.

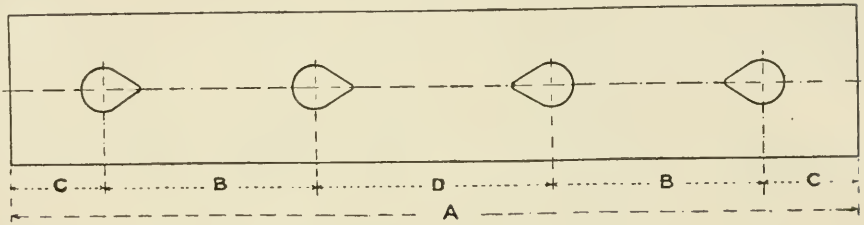
No. of B.S. Section of Rail.	70	75	80	85	90	95	100
A	3 7/32	3 7/32	3 7/16	3 1/2	3 1/2	3 1/2	3 1/2
B	1	1	1 1/16	1 1/8	1 1/8	1 1/8	1 1/8
C	9/32	9/32	5/16	21/64	21/64	21/64	21/64
D	19/32	19/32	5/8	43/64	43/64	43/64	43/64
E	1/8	1/8	1/8	1/8	1/8	1/8	1/8
F	7/16	7/16	1/2	17/32	17/32	17/32	17/32
G	4 1/16	4 1/16	4 1/16	4 1/16	4 1/16	4 1/16	4 1/16
H	7/8	7/8	15/16	1	1	1	1
I	1/2	1/2	1/2	1/2	1/2	1/2	1/2
J	3/16	3/16	3/16	3/16	3/16	3/16	3/16
K	1/16	1/32	3/64	5/64	3/64	3/64	3/64
L	17/64	1/4	1/4	9/32	1/4	1/4	1/4

No. of B.S. Section of Rail		70	75	80	85	90	95	100	Remarks.
		ins.	ins.	ins.	ins.	ins.	ins.	ins.	
Length of Fish-plates ..	A	18	18	18	18	18	18	18	
Centres of Bolt Holes in Fishplates	B	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	
	C	2	2	2	2	2	2	2	
	D	5	5	5	5	5	5	5	
Centres of Bolt-holes in Rails	B	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	
	E	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	For rails up to 45 ft. long.
		$2\frac{11}{32}$	$2\frac{11}{32}$	$2\frac{11}{32}$	$2\frac{11}{32}$	$2\frac{11}{32}$	$2\frac{11}{32}$	$2\frac{11}{32}$	For rails above 45 ft. ,,
††Clearance between Rails	F	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	*For rails up to 45 ft. ,,
		$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	†For rails above 45 ft. ,,
Dimensions of Bolt-holes in Fish-plates ..	G	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{5}{16}$	$1\frac{5}{16}$	$1\frac{5}{16}$	$1\frac{5}{16}$	
	H	$\frac{15}{16}$	$\frac{15}{16}$	1	1	1	1	1	
	I	$\frac{25}{32}$	$\frac{25}{32}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{13}{16}$	
	J	$\frac{15}{32}$	$\frac{15}{32}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	
	K	$\frac{3}{32}$ radius	$\frac{3}{32}$ radius	$\frac{3}{32}$ radius	$\frac{3}{32}$ radius	$\frac{3}{32}$ radius	$\frac{3}{32}$ radius	$\frac{3}{32}$ radius	
Dimensions of Bolt-holes in rails	L	$1\frac{1}{16}$	$1\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	For rails up to 45 ft. long
		$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{3}{16}$	$1\frac{3}{16}$	$1\frac{3}{16}$	$1\frac{3}{16}$	$1\frac{3}{16}$	For rails above 45 ft. ,,
	M	1	1	$1\frac{1}{16}$	$1\frac{1}{16}$	$1\frac{1}{16}$	$1\frac{1}{16}$	$1\frac{1}{16}$	
	N	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{17}{32}$	$\frac{17}{32}$	$\frac{17}{32}$	$\frac{17}{32}$	$\frac{17}{32}$	
		$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	
	O	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	For rails up to 45 ft. long.
Diameter of Fish-bolt ..	P	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{15}{16}$	$\frac{15}{16}$	$\frac{15}{16}$	$\frac{15}{16}$	$\frac{15}{16}$	For rails above 45 ft. ,,
WEIGHT per pair in lbs.	..	$26\frac{1}{4}$	$26\frac{1}{4}$	$29\frac{3}{4}$	$32\frac{1}{4}$	$32\frac{1}{4}$	$32\frac{1}{4}$	$32\frac{1}{4}$	

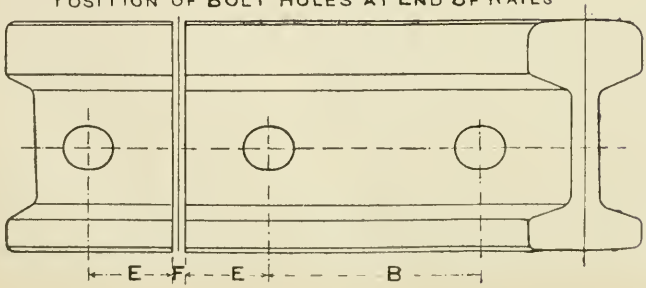
†† Measured when the holes in rails and fish-plates are concentric.
* Total allowance for expansion and contraction = $\frac{1}{2}$ inch ($\frac{3}{8}$ inch in rails and $\frac{1}{8}$ inch in fish-plates).
† Total allowance for expansion and contraction = $\frac{3}{8}$ inch ($\frac{1}{2}$ inch in rails and $\frac{1}{8}$ inch in fish-plates).

Letters refer to Diagram on page 216.

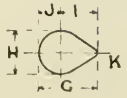
Position of Bolt Holes in Fishplates



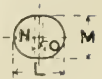
Position of Bolt Holes at End of Rails



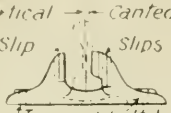
Bolt Hole in Fishplate

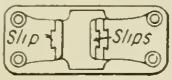


Bolt Hole in Rail



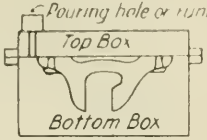
CHAIR MOULDING
Metal Pattern shewing slips





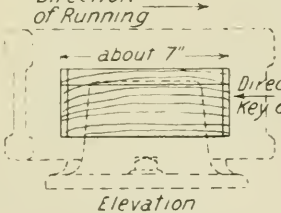
Plan

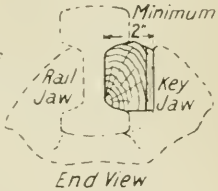
CHAIR CASTING
Mould ready for casting

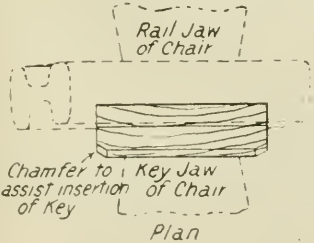


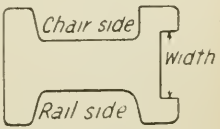
Steel template for checking castings.

Fig. 6.









Template for checking Key dimensions

Fig. 7.

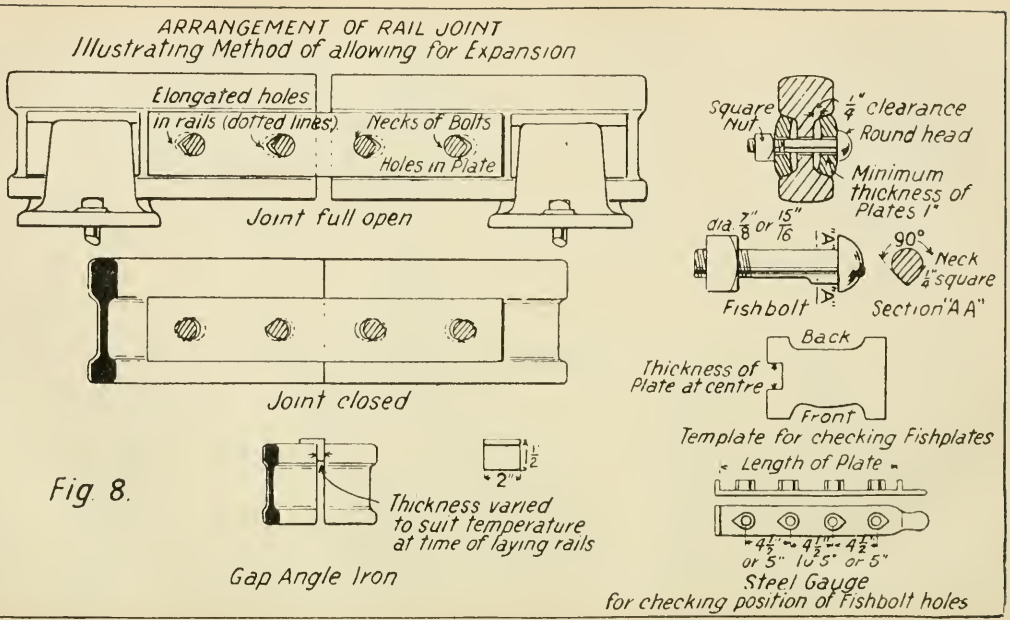
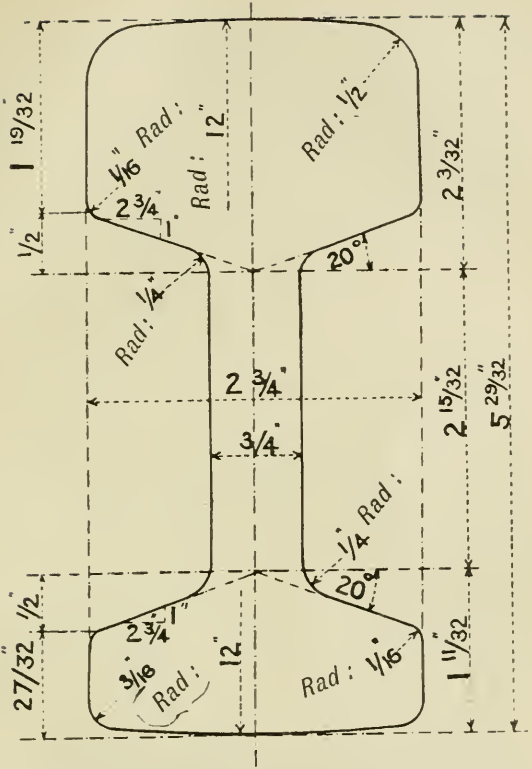
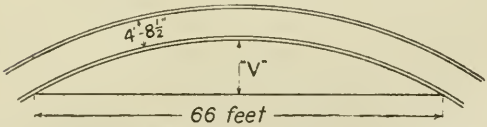

ARRANGEMENT OF RAIL JOINT
Illustrating Method of allowing for Expansion
Elongated holes
in rails (dotted lines)
Necks of Bolts
Holes in Plate
Joint full open
Joint closed
Square Nut
1/4" clearance
Round head
Minimum thickness of Plates 1"
dia 7/8" or 15/16"
90°
Neck 1/4" square
Fishbolt
Section "A A"
Back
Thickness of Plate at centre
Front
Template for checking Fishplates
Length of Plate
4 1/2" 4 1/2" 4 1/2"
or 5" or 5" or 5"
Steel Gauge
for checking position of Fishbolt holes
1 1/2"
2"
Thickness varied to suit temperature at time of laying rails
Gap Angle Iron

Fig. 8.



DIMENSIONS OF 100 LBS. "BS." BULL HEAD RAIL.



SKETCH SHOWING METHOD ADOPTED IN INTERPRETING SUPER-ELEVATION TABLES (Pages 221-222).

BALLASTING.

The "formation" level on most lines is 2′ 0″ below rail level. Rail, chair and sleeper take up about 1 foot, leaving 12 inches between under-side of sleeper and ground level at the middle of the track.

Formation level is sloped towards the sides to allow water to run to the side drains. The space between "formation" and sleeper is filled with the "bottom" ballast. Although various materials are in use for this road bed, it is now generally conceded that granite, whinstone and furnace slag are the best.

Sand, ashes and such fine material should be avoided, since in wet weather they cannot readily be drained, and in dry weather fine particles are raised by the passing vehicles, hot axles and other damage to rolling stock resulting.

Broken stone and slag have these qualities to recommend them as a bedding. They have considerable resistance to crushing, allow water to pass away freely, and true alignment is easily kept over them owing to the "bite" of the sleeper on the "bed."

Bottom ballasting material is generally broken to pass through a 3-inch ring.

Immediately under, around, and up to the top of the sleeper, the "top" ballast of smaller material is laid.

When the road bed is formed in clay or chalk, the bottom ballast should not be entirely of broken stone or slag, as these substances gradually work upwards, eventually getting into contact with the sleepers and thus ruining the drainage.

It has been found to be advantageous to spread on such beds a layer of 6″ to 9″ of ashes, with 3″ of broken stone immediately under the sleeper.

The path, or cess, outside the sleeper ends, should be slightly lower than the underside of sleeper, to facilitate drainage.

SUPER-ELEVATION.

The following instructions appertaining to the super-elevation of outer rail of curves, gauge and checking of curves, are those in use on one of the premier Railway Companies in England, and may be taken as fairly standard practice :—

In using the standard tables to find the required super-elevation, stretch a cord, 66 ft. long (1 chain) across the inner side of the Curve, measure the distance "V" between the rail and the cord, as shown in the sketch (page 219), then look for this measurement in the column headed "V" and opposite in column "R" will be found the radius of the Curve. In the other columns under "E" will be found the super-elevation required to be given to the outer rail, in inches, according to the speeds of the trains.

SUPER-ELEVATION OR CANT TO BE GIVEN TO THE OUTER RAIL OF CURVES.
4 ft. 8½ in. GAUGE.

V Distance from Cord to Rail.	R Radius of Curve.	E Super-Elevation of Outer Rail in Inches. Speed in Miles per hour.											
		15	20	25	30	35	40	45	50	55	60	65	70
Ft. In.	Chains.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
8 4	1												
4 1½	2												
2 9	3												
2 0¾	4												
1 7 13/16	5												
1 4½	6	2¼	4										
1 2⅛	7	2	3½										
1 0⅜	8	1¾	3										
11	9	1½	2¾	4¼									
10	10	1¼	2½	3¾	5½								
9	11	1¼	2¼	3½	5								
8¼	12	1	2	3	4½	6							
7⅝	13	1	1¾	2¾	4¼	5¾							
7 1/16	14	1	1¾	2¾	3¾	5¼							
6⅝	15	1	1½	2½	3½	5	6¼						

6 3/16	16	3/4	1 1/2	2 1/4	3 1/4	4 1/2	6						
5 11/16	17	3/4	1 1/2	2 1/4	3 1/4	4 1/4	5 1/2						
5 1/2	18	3/4	1 1/4	2	3	4	5 1/4	6 3/4					
5 3/16	19	3/4	1 1/4	2	2 3/4	3 3/4	5	6 1/4					
5	20	3/4	1 1/4	1 3/4	2 3/4	3 3/4	4 3/4	6					
4 1/2	22	1/2	1	1 3/4	2 1/2	3 1/4	4 1/4	5 1/2	6 3/4				
4 1/8	24	1/2	1	1 1/2	2 1/4	3	4	5	6 1/4				
3 13/16	26	1/2	1	1 1/2	2	2 3/4	3 3/4	4 3/4	5 3/4				
3 9/16	28	1/2	3/4	1 1/4	2	2 1/2	3 1/2	4 1/4	5 1/4	6 1/2			
3 5/16	30	1/2	3/4	1 1/4	1 3/4	2 1/2	3 1/4	4	5	6			
2 13/16	35		3/4	1	1 1/2	2	2 3/4	3 1/2	4 1/4	5 1/4	6 1/4		
2 1/2	40		1/2	1	1 1/4	1 3/4	2 1/2	3	3 3/4	4 1/2	5 1/4	6 1/4	
2 3/16	45			3/4	1 1/4	1 3/4	2	2 3/4	3 1/4	4	4 3/4	5 1/2	6 1/2
2	50			3/4	1	1 1/2	2	2 1/2	3	3 1/2	4 1/4	5	5 3/4
1 13/16	55			3/4	1	1 1/4	1 3/4	2 1/4	2 3/4	3 1/4	4	4 1/2	5 1/4
1 5/8	60			1/2	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4 1/4	5
1 9/16	65				3/4	1 1/4	1 1/2	1 3/4	2 1/4	2 3/4	3 1/4	4	4 1/2
1 7/16	70				3/4	1	1 1/4	1 3/4	2 1/4	2 1/2	3	3 1/2	4 1/4
1 5/16	75				3/4	1	1 1/4	1 1/2	2	2 1/4	2 3/4	3 1/4	4
1 1/4	80				3/4	1	1 1/4	1 1/2	1 3/4	2 1/4	2 3/4	3 1/4	3 3/4
1 3/16	85				3/4	3/4	1	1 1/2	1 3/4	2 1/4	2 1/2	3	3 1/2
1 1/8	90				1/2	3/4	1	1 1/4	1 3/4	2	2 1/2	2 3/4	3 1/4
1 1/16	95				1/2	3/4	1	1 1/4	1 1/2	2	2 1/4	2 3/4	3
1	100				1/2	3/4	1	1 1/4	1 1/2	1 3/4	2 1/4	2 1/2	3
7/8	110				1/2	3/4	3/4	1	1 1/4	1 3/4	2	2 1/4	2 3/4
13/16	120				1/2	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/2
11/16	140				1/2	1/2	3/4	3/4	1	1 1/4	1 1/2	1 3/4	2
5/8	160					1/2	1/2	3/4	1	1 1/4	1 1/4	1 1/2	1 3/4
9/16	180					1/2	1/2	3/4	3/4	1	1 1/4	1 1/2	1 3/4
1/2	200						1/2	1/2	3/4	1	1	1 1/4	1 1/2

EXAMPLE.—The distance between the rail and the cord is $1\frac{5}{16}$ in., on finding this in column "V" look opposite to it in column "R," and there will be given the radius of the Curve, namely, 75 chains, and in the column showing speed, 50 miles per hour, will be found 2 in., which is the super-elevation necessary to be given to the outer rail for a speed of 50 miles per hour.

As the curve is approached, the super-elevation must be gradually attained at the rate of 1 inch in each 66 feet length, and run out, at the end of the Curve, in the same way as at the approach.

It should be noted that Curves of similar radii, on the same gradient, will require a different amount of super-elevation, because the speeds of the trains will be greater on the falling, than on the rising, gradients. On gradients on single lines, the outer rail of Curves must, as a rule, be raised to suit the speeds of descending trains.

EXPANSION OF RAILS.

When relaying with rails 30 or 45 feet long, the following spaces must be left at the joints, according to the length of the rails and the temperature prevailing at the time :—

Temperature Degrees Fahrenheit.	Nature of Weather.	Spaces.	
		30 ft. Rails.	45 ft. Rails
		inch.	inch.
80	Hot Weather	$\frac{1}{8}$	$\frac{3}{16}$
60	Moderately Cool ..	$\frac{3}{16}$	$\frac{1}{4}$
32	Cold	$\frac{1}{4}$	$\frac{3}{8}$

Small iron expansion gauges must be used, equal in thickness to the respective spaces given above. Wooden gauges must on no account be used. The gauges must remain in the joints until the rails are properly fished up, or the expansion allowance may be lost when "butting up the rails" when linking in.

GAUGE, AND CHECKING OF CURVES.

In Curves of 10 chains radius and above, the gauge of the road must be maintained at the standard width of 4 feet $8\frac{1}{2}$ inches; but in Curves of less than 10 chains radius it may be slightly widened according to the radius of the Curve and other circumstances.

In checking Curves, the check rail must extend, when possible, for a length of 60 feet beyond the commencing and finishing points of the Curve. Check chairs, giving a clearance of $1\frac{3}{8}$ in., must be used in Curves of 10 chains radius and over. Where the radius is under 10 chains the clearance should be 2 inches

SWITCHES AND CROSSINGS

Switches.

Design.—They are termed right or left-hand pairs, according as they divert a train to the right or left when running through them. A pair consists of two movable tongues and two outer rails termed stocks. The tongues are tapered to a very fine edge at the point or nose, the length of the planing depending on that of the switches.

There is no uniformity among the railway companies in reckoning the length, the joint of the tongue being at various openings from the back rails, but if the distance from nose to where the opening from stock is $4\frac{1}{2}''$ (running faces) be taken in every case it would form a means of comparison. In any case the joint must be so placed as to give the flangeway clearance between the rails, also the travel of the toe must be sufficient to provide this clearance throughout the length of the planing. As ordinary chairs cannot be used, on account of the movement of the blades, other means of keeping gauge and inclination have to be adopted.

This is done by providing slide chairs where the movement exceeds $\frac{1}{4}''$, bolted to stock rail, and tie rods between the tongues. Where the blades separate from the stocks, the chair bolts have studs for the webs of the tongues to bear against, preventing spread.

The toe being the point where the deflecting force comes into play, special means to prevent spread have to be made, either by a tie rod just in front, or a tie plate on sleeper bolted through with chairs.

The stocks are extended both ways beyond the tongues, to obviate the tendency to "rock," as is the case with short switches; this effect is also minimized where the toes are housed under the stocks.

There are several methods of planing the nose, the commonest being to plane down the head gradually to depth of flange; another is to plane down similarly, but to house under the stock; lastly the point is planed down about $\frac{1}{2}''$ and the stock rail set out to cover the stub point; in the last method the nose is stouter and stronger than the other two methods.

Manufacture.—In all cases bending is done cold. The stock rails are cut to dead length at the cold saw.

The sawn rails are drilled for fish and chair holes.

The tongues are similarly sawn and drilled; they next go to the hydraulic bender to be set; the length of planing is set off from a template and rails given a straight bend at that point. The object of bending the rail is obvious—to bring web central at toe. The backs of the rails are next planed to the exact profile if required to fit under head of stocks. The front top and finishing planing follow, and they are then taken to the fitting benches to be fitted up with stocks, chairs, connecting and tie-rods

complete, then carefully gauged, the flangeways being also checked. (See Fig. 9. page 227).

Crossings.

Design.—The built-up form is the commonest and most preferred. It consists of two spliced rails forming the "Vee" and two wing rails, the latter being running rails for only a part of their length.

Guard rails, one for each road, are also provided to prevent the nose of "vee" being struck by wheels wandering across the gap. The length overall of the crossing should be sufficient to counteract any tendency to "rock." All running rails should be canted normal to the cones of the tyres, and checks or guards vertical, since it is the backs of the wheel flanges which come in contact with them.

The flangeway clearances should be run out gradually to prevent shock.

The "vee" is centred between the wings at an interval equal to the flangeway, this being maintained by distance or blocking pieces, and the whole connected securely by through bolts. Special chairs have to be used except where the offset between the rails is sufficient to allow of the ordinary ones being inserted.

Manufacture.—The guard rails are simply bent at the press, the set being checked by a slip gauge.

The "vee," consisting of a point rail (which is the through rail, and has the nose formed at the end) and the splice rail, which does not extend so far as the former, has both rails set before planing. Then the splice rail is planed on back, the point rail similarly to a common profile. They are next bolted together and the running faces then planed to form the nose; the finishing planing follows, bolts being removed and rivets substituted.

The wings are bent in the press and the portion that is to become the running rails is canted 1 in 20, or 1 in 24, as the case may be. They are then ready for fitting to the "vee." This is done on a bench, where all blockings, through bolts and chairs are added, thus completing the crossing. The guards simply have their check chairs keyed on before delivery at site.

Block Fittings,

e.g., diamonds, single and double compounds, and special linked up switches and crossings, are generally manufactured in the shops and fitted together before despatch to site; this procedure ensures the gauge and alignment being satisfactory. The method of working to wooden templates of blocks of fittings is antiquated. A large scale diagram of the block (say to 8 ft. or 4 ft. scale) is far more convenient, greater accuracy being attained by the latter method, since in the former much depends on the correct piecing together of the template sections, which in transit frequently get broken, distorted or warped

DIAMONDS.—When one road crosses another a diamond is formed. It consists of two end crossings and two "elbows" with guards to each. The manufacture of the elbows is all that need be described. An elbow is made up of a back rail, two point rails and an inside check rail. The back rail is simply bent at centre to an angle supplementary to that of the crossing angle, also it is canted 1 in 20 or so for both roads it is to form.

The point is first set, then planed both sides of head only, to form the nose. The inside check is bent similarly to the back rail, but is not canted; another bend at the ends is put in to grade out the flangeway clearance. The elbow is fitted up complete with back, points and check rails, blocking pieces and special chairs.

COMPOUNDS.—The tracks forming a diamond are frequently connected by "slips" forming single or double compounds, according as one or two slips are inserted.

The manufacture of all the component parts has been described above.

SWITCH DIAMONDS.—The Board of Trade do not permit the laying in of elbows flatter than 1 in 8 angle with fixed points. To overcome this limitation switch diamonds have been devised, where four sliding points or switches are substituted for the fixed ones. The tongues are coupled up in pairs and worked by a rocking lever in opposite directions. Thus a through road is provided in lieu of gaps. The planing of the tongues is necessarily short, on account of the angle of divergence being greater than with ordinary switches, consequently lateral support has to be provided for the switch to shut up against, this being effected by auxiliary rails to which the slide chairs are bolted; they are extended past the heel of the points, and two or three chairs on each side are bolted through both rails, thus giving the necessary rigidity.

There are the usual connecting rods to hold the blades together.

TIMBERS.—All crossing work should be laid on through timbers, as the subsequent maintenance will be considerably lightened thereby, and the heavy and solid block thus formed is not likely to get knocked out of alignment.

DOUBLE JUNCTIONS.—The provision of flat easy junctions is now possible without having recourse to widening out the lines to bring the angle of the elbows within the Board of Trade regulation, by the insertion of switch diamonds described above. For a 6′ 6″ interval between tracks (running faces), the flattest curve attainable for 1 in 8 fixed elbows is 1,200′ radius, giving a short length of straight before entering the elbows, thus obviating the outer rail point being unduly struck. The leading crossings would be of angle 1 in $11\frac{1}{2}$, and deflection angle of switches should not be less than 1 in 48.

The speed restriction over such a junction is 25 miles per hour.

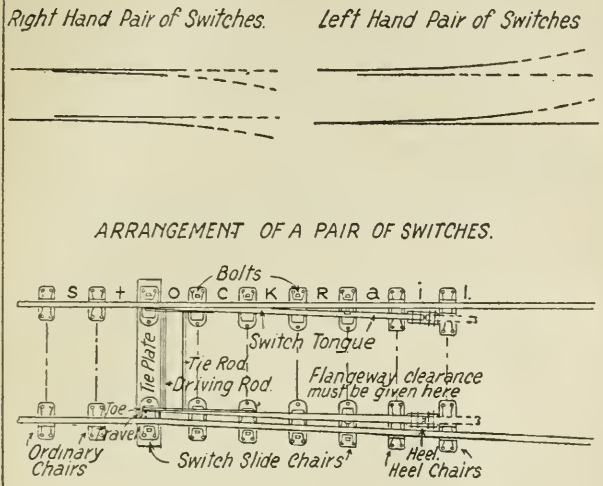

Right Hand Pair of Switches.
Left Hand Pair of Switches
ARRANGEMENT OF A PAIR OF SWITCHES.
Bolts
Switch Tongue
Tie Plate
Tie Rod
Driving Rod
Flangeway clearance must be given here
Toe
Heel
Ordinary Chairs
Switch Slide Chairs
Heel Chairs
METHODS OF PLANING SWITCH TONGUES
Stock Rail.
Web
Bend
1¼"
Housing
Stock Rail.
Bend
1¼"
Stock Rail.
Stock Set Out
A
B
Bend
½"
Profile at B at A

Fig. 9.

ARRANGEMENT OF ORDINARY CROSSING.

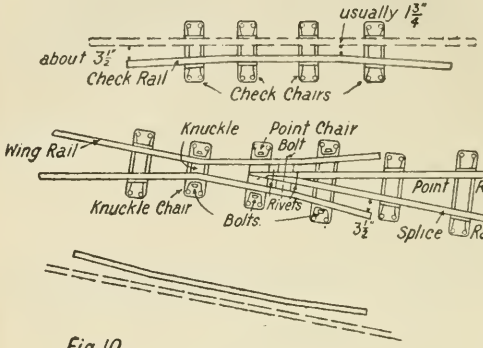
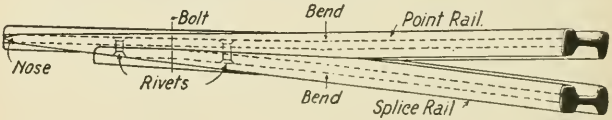


Fig. 10.

DETAIL SKETCH OF VEE SPLICE.



ARRANGEMENT OF DIAMOND.

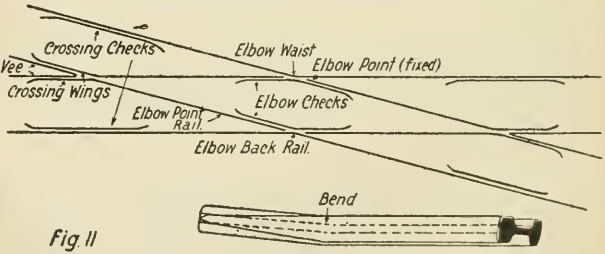


Fig. 11

Planing of Elbow Point.

With movable points angle 1 in 10¼, the turnout radius may be 2,350′. The leading angles are in this case 1 in 16, and angle of divergence of switches 1 in 80. The speed restriction over such a junction might be 35 miles per hour. In both cases cited above the main lines are taken as straight, consequently there would not be any restriction of speed over them.

"Limits" Switches.—The angle of deflection for goods lines should not be less than 1 in 26·7; for main lines 1 in 37·3, or 10′ and 14′ to the 4½″ opening respectively.

For fast double junction 1 in 80 is a suitable angle for the switches.

"Limits" Crossings.—Angles sharper than 1 in 2 are rarely made of the built-up type, as this is considered the limiting angle for bending the wings, and below this the length of splice is insufficient for secure fastening.

The higher limit seems to be about 1 in 70, there being many crossings of this angle in existence. The length of gap comes into the question and deters one from going much beyond the above flat angle.

Life.—Under ordinary conditions, in main lines free from very sharp curves, and abnormal shunting, the life of fittings is from 14-17 years.

SETTING OUT PERMANENT-WAY.

The curves generally used in railway work are either circular or parabolic.

For the reason that its rate of deflection is constant, the circular curve is used for all ordinary purposes, the parabolic curve being introduced for transition purposes between circular curves and straight, or between two circular curves of greatly varying radii.

Circular curves are spoken of as (I.) Simple—having the same radius throughout. (II.) Compound—being two or more circular arcs having a common tangent at their point of junction. (III.)—Reverse—consisting of two curves of the same or differing radii running in opposite directions.

In England curves are described by the lengths of their radii, but in America and other countries they are described as 1 degree, 2 degrees, etc., curves, according to the angle subtended by 100 ft. chord at the centre (see Fig. 1).

Thus a 1-degree curve has a radius of 5,730 ft., and a 2-degree curve a radius half as much. The radius may be found from the equation $R = \frac{\frac{1}{2}\text{ chord.}}{\text{Sin } \alpha}$

There are various methods of setting out circular curves, but the one generally used is that suggested by Rankine, which will be found to work well for curves not exceeding 300 chains rad. The method of procedure is as follows:—

It is usual to make a careful survey of the site on which the lines of straight and radii of the curves to be used are approximately determined. The straights or tangents, as they are called, are then ranged out on the ground and the angles between them measured with a theodolite. Having determined the angle of deflection on the ground, we may proceed, with the radius on the plan, to calculate the exact length of each tangent and the length of the curve.

Fig. 2.

Let B A D = deflection angle, then since the tangents are at right angles to the radius, the angles D H C and B A D will be equal, and if R be the radius the length of the tangents A D or A C will be $R \times \tan. \frac{1}{2}$ B A D. The length of curve D C $= 2\pi R \frac{(B A D)}{360}$ Where $\pi = 3{\cdot}1416$ and B A D = angle in degrees. Other information which may be useful for checking, etc., may be found from the following formulæ.

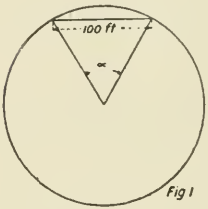


Fig 1

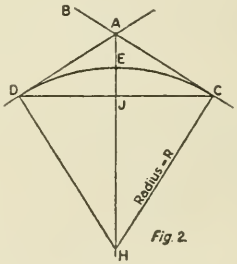


Fig. 2.

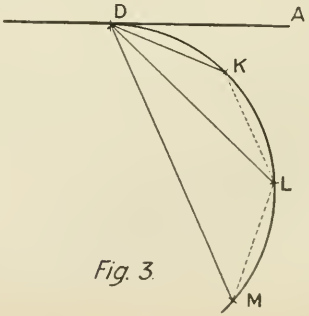


Fig. 3.

$$A\,E = R\ (\sec.\ \tfrac{1}{2}\ B\,A\,D - 1).$$
$$E\,J = R\ (1 - \cos\ \tfrac{1}{2}\ B\,A\,D).$$
$$D\,J = R \sin\ \tfrac{1}{2}\ B\,A\,D.$$
$$R = \frac{A\,D}{\tan\ \tfrac{1}{2}\ B\,A\,D}$$

Having calculated the length of the tangents these are measured out on the ground from the intersection point A and the theodolite set up at either of the tangent points D or C. From either of these points equal angles A D K, K D L, L D M, etc., are set off and equal arcs D K, K L, L M, etc, measured from D, give points on the curve (see Fig. 3). It is usual to assume for practical purposes that the arcs D K, K L, etc., are the same length as the chords D K, K L, etc., and to measure the chords as shown in dotted lines, making allowances for the difference in length only in the case of very sharp curves.

It is usual to adopt a chord length of 66 ft. except in curves of less than 20 chains radius in which 33 ft. chords are desirable.

A D K. The tangential angle in minutes $= \frac{1719}{R}$ where R = radius in chord lengths.

In actual practice it is not desirable to set out a greater length than five chains from one point, after which the instrument should be moved. Thus if it is required to extend the curve from L, if we set the vernier plate to the angle for 1 chord length, *viz.*, the angle A D K, and look on the point M, the angle for 2-chord lengths will give the next point on the curve. The curve should be checked by calculating the distance to the middle point A E, and if the end of the curve does not work out to an even chord length the remaining length should be measured and checked with the calculated length of the curve D.C. The tangential angle for the odd chord length will be in the proportion of the odd to the full chord length. The total of the tangential angles should be equal to half the deflection angle.

On pages 239-250 will be found tables giving lengths of tangents, etc., for deflection angles up to 70 degrees, and tables giving tangential angles for curves up to 500 chains radius on pages 251 to 255, and explanations of same on pages 237 and 238.

Curves over 300 chains in radius are more accurately set out by reading the deflection angle and calculating the distance A E as before, after which the remaining points should be put in as follows. At the mid-point of the line joining D E put the offset $x = \frac{1}{4}$ A E and at the mid-point of the chords E F and F D put the offset $y = \frac{1}{4}x$. and so on until the required number is obtained. (See Fig. 4).

TRANSITION CURVES.

The object of transition curves is to ease the running at the tangent points of straight and sharp curves, and to obviate the need of running the cant up on the straight.

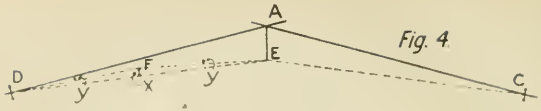


Fig. 4.

The type of transition curve generally used in this country is the cubic parabola and is so proportioned as to give the theoretical cant at all points on the curve when running it up at a constant grade.

In working out a transition curve it is first necessary to determine the radius of the circular curve and the superelevation to be adopted on same.

The superelevation may be determined by any method, but the one most generally used is the formula.

$$K = \frac{Gv^2}{gr}$$

Where K = superelevation.
G = gauge of line.
v = velocity in ft. per second.
g = 32·2 ft. per sec.^{2}=acceleration due to gravity
r = radius of line in ft.

Having determined the cant, the grade at which it is to be run up must be decided and this should not be steeper than 1″ in a chain where full speeds are allowed.

The length of the transition curve will then be equal to the amount of cant multiplied by the gradient. Thus if the cant is 3″ and the gradient 1″ in 66′ 0″, L=the length of transition=3×68=198′ 0″.

The shift or amount the circular curve has to be moved to allow of the necessary flattening is

$$S = \frac{\frac{1}{2}L^2}{6R}$$

Where L=length of transition.
R=radius of circular arc.

In setting out transition curves it is usual to leave some permanent marks, such as concrete blocks, which indicate the centre line and the amount of cant. It is therefore desirable to place these blocks at intervals corresponding to say each $\frac{1}{2}$″ of cant, which, if the cant is 1″ in 66′ 0″, will be 33′ 0″ apart. The offsets must therefore be worked out for every half-chain and may be found from the formula

$$y = \frac{x^3}{6LR}$$

Where y=offset from straight at any distance.
x from the tangent point A.

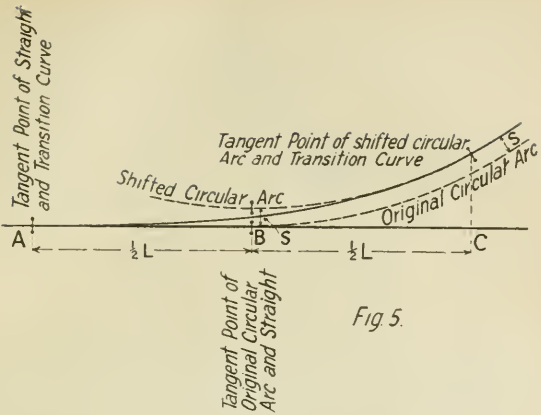


Fig 5.

The offsets may be very quickly worked out from this formula with a table of logarithms, since the denominator is the same for any value of x. The offset at B=½S and the offset at C=4S. Half the length of the transition curve is placed on each side of the tangent point of the original circular arc.

In setting out circular curves with transitions the tangents are ranged out as for ordinary circular curves, but before the curve is pegged out it is necessary to move the tangents by the amount of shift (see Fig. 6), the circular curve being then set out as before. The transition curve may be pegged out from a string line on the original straight. The above sketch shows the setting out for a reverse curve.

Transition curves are not generally used where the circular arc is over 80 chains radius as the shift is then so small as to be negligible.

Curves are generally marked on the ground by means of pegs in the top of which a small nail is driven to indicate the exact position, concrete blocks being afterwards substituted if required.

CROSSING WORK.

Crossing work may be either set out on the ground or the angles and distances calculated or drawn out in the office. Generally speaking the former method is more convenient where the work has to fit in with other junctions, or in cases where main lines are curved and not parallel, but in laying out new yards, etc., where there is no existing work to interfere with, the calculation method is preferable.

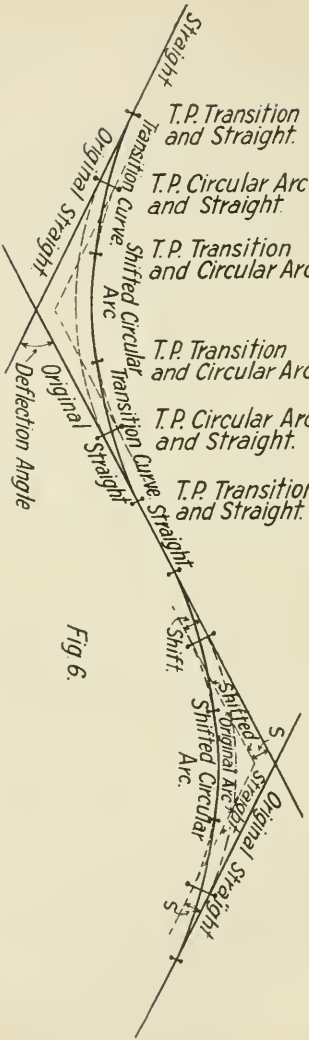
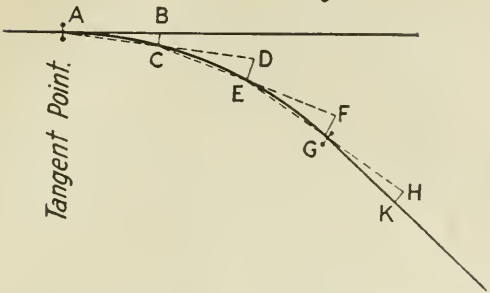

Straight
T.P. Transition and Straight.
Original Straight
Transition Curve
T.P. Circular Arc and Straight.
Shifted Circular Arc
T.P. Transition and Circular Arc.
T.P. Transition and Circular Arc.
Original Deflection Angle
Straight
T.P. Circular Arc and Straight.
Transition Curve
T.P. Transition and Straight.
Straight
Shift
Shifted Original Arc
Straight
Original Straight
Shifted Circular Arc.
S
S

Fig 6.

I. Chord and Offset. Fig. 7.



In crossing work long curves are set out with a theodolite as before described, but in ordinary turnout work the curves are so short that sufficient accuracy is obtained by one or other of the string line methods, which are sufficiently near to make it a matter of convenience on the site as to which one is used.

There is some difference in practice as to the method of leaving the main line at switches. One method is to set the curve round from a true tangent on the main line, inserting the heel of the switch at the $4\frac{1}{2}''$ opening, the other is to commence the curve tangential from the heel of the switches. The latter method is obviously the more correct one, as in the former we have the same length of lead for any given curve, no matter at what angle the switch deviates from the main line.

In the first case it is necessary to find a line from which to start the curve, and this may be done by putting up the centre line if the main line is straight or by picking up a tangent on the centre line at the intended point of departure if it is curved, the turnout curve being set out from this line by one of the following methods.

I.—Chord and Offset. Fig. 7.

Offset from tangent $BC = \frac{\text{chord}^2}{2 \text{ Radius}}$

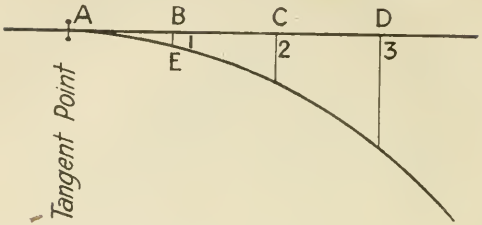
Offset from chord produced $D E = \frac{\text{chord}^2}{\text{radius}}$

Assume length of chord say 10 or 15 ft.

Measure out A B = 1 chord length and give offset B C.

Measure out another chord length C D and pulling over point C give offset D E. Then pulling from C through point E chord length E F give offset F G = D E and so on. If it be required to find a tangent at say G, pull line from E over G to H and give offset H K equal to first offset B C.

II. Offset from Tangent. Fig. 8.



II.—Offset from Tangent. Fig. 8.

Offset No. $1 = \frac{\text{chord}^2}{2 \text{ Radius}}$

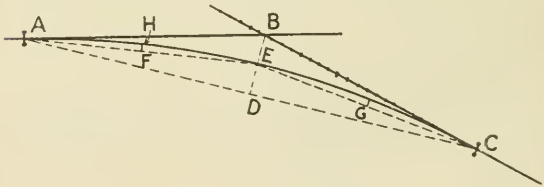
Remaining offsets may be found by multiplying offset No. 1 by the square of the number of offset

Thus, Offset No. $2 = \text{B E} \times 2^2$

,, ,, No. $3 = \text{B E} \times 3^2$

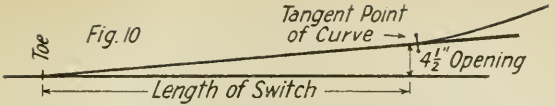
The chord lengths are assumed as before and the offsets given at right angles to the tangent. This method should only be used where the deflection of the curve is small, as it is really a parabolic curve.

III. Chords and versed-sines. Fig. 9.



III.—Chords and versed-sines. Fig. 9.

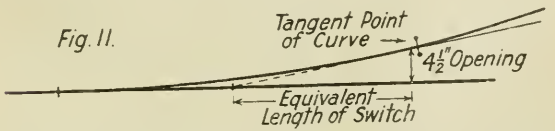
This method is most convenient where two fixed lines of straight have to be connected by a curve. First measure out the two equal tangents B A and B C, then pull up the chord A C and measure the distance to the intersection B D. Half this distance will give the mid-point of the curve E. From E another chord is used to connect A, and at its mid-point F give offset $\text{F H} = \frac{1}{4} \text{ E D}$. Similarly, if further points on the curve are required other chords, such as H E, may be used, giving $\frac{1}{4}$ of offset F H at the centre. The radius of the curve may be found from the formula $\frac{\frac{1}{2} \text{ AC}^2}{\text{BD}}$



All of the foregoing methods are only approximate, but in curves of the length usually found in crossing work the error is negligible.

Having set out the curve tangential with the main line, the 4½" opening is measured and the heel of the switch pegged in at that point. The 4½" is the usual opening at the heel of switches, being made up of the width of the rail, 2¾", and the flangeway clearance, 1¾".

If it is required to take the length of the switch into consideration in setting out the turnout, this may be done in the case of straight switches by measuring out the length of the switch and pulling a line from the toe over the 4½" opening, using this as the tangent from which to set out the curve as shown on Fig. 10.



If the switches are curved it is necessary to find the distance on the main line centre at which a tangent at the heel would cut, and a line pulled from that point over the 4½" opening would give the tangent from which to commence setting out the curve. (See Fig. 11.)

Having set out the curve, the crossing is taken by putting up lines at half gauge from the centre of the main line and turnout, and measuring the distance between the 6" openings on each side of the intersection, which gives the angle of the crossing. It is usual to leave a peg under the intersection of the crossing for the guidance of the relaying ganger.

CURVE TABLES.

The following tables give pratically all the information required for setting out curves on the method described on page 229, and are intended to avoid the necessity for carrying a large book of mathematical tables.

From Table I. may be obtained the lengths of tangents, subtangents, position of mid-points of curve and length of curve, by multiplying the value opposite the required deflection angle by the radius, the radius being in whatever units the answer is required—that is to say, if the radius is in feet the length of tangents, etc., will be in feet, or if the radius is in chains the answer will be in chains.

Column (a) gives the deflection angle B A D.
,, (b) ,, ,, lengths of tangents A C and A D.
,, (c) ,, ,, lengths of subtangents E F and F D.
,, (d) ,, ,, distance to mid-point A E.
,, (e) ,, ,, do. for sub-tangents F G.
,, (f) ,, ,, length of curve D G E C.

The table gives the figures for every tenth minute in the main columns and in the difference column is given the difference for 1 minute. This must be multiplied by the number of odd minutes required and added to the figure in the main column, **keeping the extreme right-hand figure of the difference one place to the right of the last figure in the main column.** Thus, supposing it is required to find the length of tangent for a 40 chains radius curve having a deflection angle or 20° 23½′.

Opposite 20° 20′, in column (b), we have ·17933 and in the adjoining small column the difference for 1′=150; multiply this by the number of odd minutes, we get $150 \times 3\frac{1}{2} = 525$. Therefore ·17933

$$\underline{525}$$

·179855 is the value for 20° 23½′.

Multiply by radius $\underline{40}$

and we get $7 \cdot 194200 = 7$ chs. 19·42 links.

The other columns may be worked out in the same way.

Table II. gives the tangential angles for setting out curves in one chain arcs up to 10 chains in length for various radii, and will be found to save much time in working these angles on the ground.

These angles are calculated from $\frac{1719}{R}$ as described on page 231.

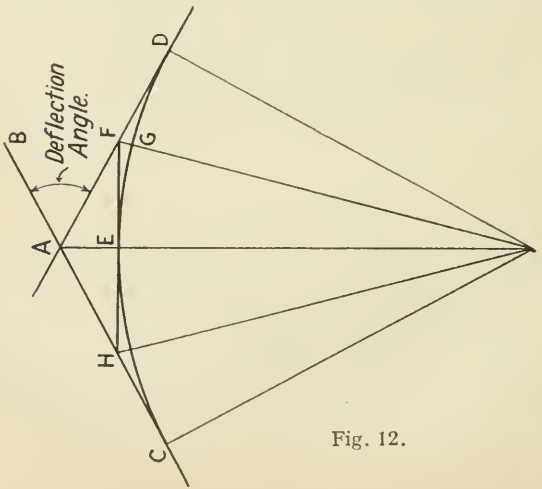


Fig. 12.

TABLE 1.

Deflection Angle B A D.	Tangents A D and A C.	Difference for 1′	Sub-tangents D F and F E.	Difference for 1′	Secant—Rad. A E.	Difference for 1′	Sub-Secant—Rad. F G.	Difference for 1′	Length of Curve D G E C.	Difference for 1
(a)	(b)		(c)		(d)		(e)		(f)	
0° 0′	—	—	—	—	—	—	—	—	—	—
0° 10′	·00145	145	·00072	073	—	—	—	—	·00291	291
0° 20′	·00291	145	·00145	073	—	—	—	—	·00582	291
0° 30′	·00436	145	·00218	073	·00001	001	—	—	·00873	291
0° 40′	·00582	145	·00291	073	·00002	001	—	—	·01163	291
0° 50′	·00727	145	·00363	073	·00003	001	·00001	—	·01454	291
1° 00′	·00873	145	·00436	073	·00004	001	·00001	—	·01745	291
1° 10′	·01018	145	·00509	073	·00005	001	·00001	—	·02036	291
1° 20′	·01164	145	·00582	073	·00007	001	·00002	—	·02327	291
1° 30′	·01309	145	·00655	073	·00008	001	·00002	—	·02618	291
1° 40′	·01454	145	·00727	073	·00010	002	·00003	—	·02909	291
1° 50′	·01600	145	·00800	073	·00013	002	·00003	—	·03200	291
2° 00′	·01745	145	·00873	073	·00015	002	·00004	—	·03491	291
2° 10′	·01891	145	·00946	073	·00018	003	·00004	—	·03782	291
2° 20′	·02036	145	·01018	073	·00021	003	·00005	—	·04072	291
2° 30′	·02182	145	·01091	073	·00024	003	·00006	001	·04363	291
2° 40′	·02327	145	·01164	073	·00027	003	·00007	001	·04654	291
2° 50′	·02473	145	·01237	073	·00030	003	·00007	001	·04945	291
3° 00′	·02618	145	·01309	073	·00034	004	·00008	001	·05236	291
3° 10′	·02764	145	·01382	073	·00038	004	·00009	001	·05527	291
3° 20′	·02910	145	·01454	073	·00042	004	·00010	001	·05818	291
3° 30′	·03055	145	·01528	073	·00047	004	·00012	001	·06109	291
3° 40′	·03201	145	·01600	073	·00051	004	·00013	001	·06400	291
3° 50′	·03346	145	·01673	073	·00056	005	·00014	001	·06690	291
4° 00′	·03492	146	·01745	073	·00061	005	·00015	001	·06981	291
4° 10′	·03638	146	·01819	073	·00066	005	·00016	001	·07272	291
4° 20′	·03783	146	·01891	073	·00071	005	·00018	001	·07563	291
4° 30′	·03929	146	·01964	073	·00077	005	·00019	001	·07854	291
4° 40′	·04075	146	·02036	073	·00083	006	·00021	001	·08145	291
4° 50′	·04220	146	·02110	073	·00089	006	·00022	001	·08436	291
5° 00′	·04366	146	·02182	073	·00095	006	·00024	001	·08727	291
5° 10′	·04512	146	·02255	073	·00102	006	·00025	002	·09017	291
5° 20′	·04657	146	·02327	073	·00108	006	·00027	002	·09308	291
5° 30′	·04803	146	·02401	073	·00115	007	·00029	002	·09599	291
5° 40′	·04949	146	·02473	073	·00122	007	·00030	002	·09890	291
5° 50′	·05095	146	·02546	073	·00130	007	·00032	002	·10181	291

TABLE 1—(*continued*).

Deflection Angle B A D.	Tangents A D and A C.	Difference.	Sub-tangents D F and F E.	Difference.	Secant—Rad. A E.	Difference.	Sub-Secant—Rad. F G.	Difference.	Length of Curve D G E C.	Difference.
(a)	(b)		(c)		(d)		(e)		(f)	
6° 00′	·05241	146	·02618	073	·00137	007	·00034	002	·10472	291
6° 10′	·05387	146	·02692	073	·00145	008	·00036	002	·10763	291
6° 20′	·05532	146	·02764	073	·00153	008	·00038	002	·11054	291
6° 30′	·05678	146	·02837	073	·00161	008	·00040	002	·11345	291
6° 40′	·05824	146	·02910	073	·00169	008	·00042	002	·11636	291
6° 50′	·05970	146	·02983	073	·00178	009	·00044	002	·11926	291
7° 00′	·06116	146	·03055	073	·00187	009	·00047	002	·12217	291
7° 10′	·06262	146	·03128	073	·00196	009	·00049	002	·12508	291
7° 20′	·06408	146	·03201	073	·00205	009	·00051	002	·12799	291
7° 30′	·06554	146	·03274	073	·00214	009	·00053	002	·13090	291
7° 40′	·06700	146	·03346	073	·00224	010	·00056	002	·13381	291
7° 50′	·06846	146	·03420	073	·00234	010	·00058	002	·13672	291
8° 00′	·06993	146	·03492	073	·00244	010	·00061	002	·13963	291
8° 10′	·07139	146	·03565	073	·00254	010	·00063	002	·14254	291
8° 20′	·07285	146	·03638	073	·00265	011	·00066	003	·14544	291
8° 30′	·07431	146	·03711	073	·00276	011	·00068	003	·14835	291
8° 40′	·07577	146	·03783	073	·00287	011	·00071	003	·14126	291
8° 50′	·07724	146	·03857	073	·00298	011	·00074	003	·15417	291
9° 00′	·07870	146	·03929	073	·00309	011	·00077	003	·15708	291
9° 10′	·08016	146	·04002	073	·00321	012	·00080	003	·15999	291
9° 20′	·08163	146	·04075	073	·00333	012	·00083	003	·16290	291
9° 30′	·08309	146	·04148	073	·00345	012	·00085	003	·16581	291
9° 40′	·08456	146	·04220	073	·00357	012	·00089	003	·16872	291
9° 50′	·08602	146	·04294	073	·00369	012	·00092	003	·17162	291
10° 00′	·08749	146	·04366	073	·00382	013	·00095	003	·14753	291
10° 10′	·08895	146	·04439	073	·00395	013	·00098	003	·17744	291
10° 20′	·09042	146	·04512	073	·00408	013	·00102	003	·18035	291
10° 30′	·09189	146	·04585	073	·00421	013	·00105	003	·18326	291
10° 40′	·09335	146	·04657	073	·00435	014	·00108	003	·18617	291
10° 50′	·09482	146	·04731	073	·00448	014	·00111	003	·18908	291
11° 00′	·09629	147	·04803	073	·00462	014	·00115	004	·19199	291
11° 10′	·09776	147	·04877	073	·00477	014	·00119	004	·19490	291
11° 20′	·09922	147	·04949	073	·00491	014	·00122	004	·19780	291
11° 30′	·10069	147	·05022	073	·00506	015	·00126	004	·20071	291
11° 40′	·10216	147	·05095	073	·00520	015	·00130	004	·20362	291
11° 50′	·10363	147	·05168	073	·00535	015	·00134	004	·20653	291

TABLE 1—(*continued*).

Deflection Angle B A D.	Tangents A D and A C.	Difference.	Sub-tangents D F and F E.	Difference.	Secant—Rad. A E.	Difference.	Sub-Secant—Radius F G.	Difference.	Length of Curve D G E C.	Difference.
(a)	(b)		(c)		(d)		(e)		(f)	
12° 00′	·10510	147	·05241	073	·00551	015	·00137	004	·20944	291
12° 10′	·10657	147	·05314	073	·00566	015	·00141	004	·21235	291
12° 20′	·10805	147	·05387	073	·00582	016	·00145	004	·21526	291
12° 30′	·10952	147	·05460	073	·00598	016	·00149	004	·21817	291
12° 40′	·11099	147	·05532	073	·00614	016	·00153	004	·22107	291
12° 50′	·11246	147	·05606	073	·00630	016	·00157	004	·22398	291
13° 00′	·11393	147	·05678	073	·00647	017	·00161	004	·22689	291
13° 10′	·11541	147	·05752	073	·00664	017	·00165	004	·22980	291
13° 20′	·11688	147	·05824	073	·00681	017	·00169	004	·23271	291
13° 30′	·11836	147	·05898	073	·00698	017	·00174	004	·23562	291
13° 40′	·11983	147	·05970	073	·00715	017	·00178	004	·23853	291
13° 50′	·12131	147	·06044	073	·00733	018	·00182	004	·24144	291
14° 00′	·12278	148	·06116	073	·00751	018	·00187	005	·24435	291
14° 10′	·12426	148	·06190	073	·00769	018	·00191	005	·24726	291
14° 20′	·12574	148	·06262	073	·00787	018	·00196	005	·25016	291
14° 30′	·12722	148	·06336	073	·00806	019	·00200	005	·25307	291
14° 40′	·12869	148	·06408	073	·00825	019	·00205	005	·25598	291
14° 50′	·13017	148	·06482	073	·00844	019	·00210	005	·25889	291
15° 00′	·13165	148	·06554	073	·00863	019	·00214	005	·26180	291
15° 10′	·13313	148	·06628	073	·00882	019	·00219	005	·26471	291
15° 20′	·13461	148	·06700	073	·00902	020	·00224	005	·26762	291
15° 30′	·13609	148	·06774	073	·00922	020	·00229	005	·27053	291
15° 40′	·13757	148	·06846	073	·00942	020	·00234	005	·27343	291
15° 50′	·13906	148	·06920	073	·00962	020	·00239	005	·27634	291
16° 00′	·14054	148	·06993	073	·00983	021	·00244	005	·27925	291
16° 10′	·14202	148	·07066	073	·01003	021	·00249	005	·28216	291
16° 20′	·14351	148	·07139	073	·01024	121	·00254	005	·28507	291
16° 30′	·14499	148	·07212	073	·01046	021	·00260	005	·28798	291
16° 40′	·14648	148	·07285	073	·01067	021	·00265	005	·29089	291
16° 50′	·14796	149	·07358	073	·01089	022	·00270	005	·29380	291
17° 00′	·14945	149	·07431	073	·01111	022	·00276	005	·29671	291
17° 10′	·15094	149	·07505	073	·01133	022	·00281	005	·29961	291
17° 20′	·15243	149	·07577	073	·01155	022	·00287	005	·30252	291
17° 30′	·15391	149	·07651	073	·01177	022	·00292	006	·30543	291
17° 40′	·15540	149	·07724	073	·01200	023	·00298	006	·30834	291
17° 50′	·15689	149	·07797	073	·01223	023	·00303	006	·31125	291

TABLE 1—(*continued*),

Deflection Angle B A D.	Tangents A D and A C.	Difference.	Sub-tangents D F and F E.	Difference.	Secant—Rad. A E.	Difference.	Sub-Secant—Radius F G.	Difference.	Length of Curve D G E C.	Difference.
(a)	(b)		(c)		(d)		(e)		(f)	
18° 00′	·15838	149	·07870	073	·01246	023	·00309	006	·31416	291
18° 10′	·15987	149	·07944	073	·01270	023	·00315	006	·31707	291
18° 20′	·16137	149	·08016	073	·01294	024	·00321	006	·31998	291
18° 30′	·16286	149	·08090	073	·01317	024	·00326	006	·32289	291
18° 40′	·16435	149	·08163	073	·01342	024	·00333	006	·32579	291
18° 50′	·16585	150	·08236	073	·01366	024	·00338	006	·32870	291
19° 00′	·16734	150	·08309	073	·01390	024	·00345	006	·33161	291
19° 10′	·16884	150	·08383	073	·01415	025	·00350	006	·33452	291
19° 20′	·17033	150	·08456	073	·01440	025	·00357	006	·33743	291
19° 30′	·17183	150	·08529	073	·01465	025	·00363	006	·34034	291
19° 40′	·17333	150	·08602	073	·01491	025	·00369	006	·34325	291
19° 50′	·17483	150	·08676	073	·01517	026	·00375	006	·34616	291
20° 00′	·17633	150	·08749	073	·01543	026	·00382	006	·34907	291
20° 10′	·17783	150	·08822	073	·01569	026	·00388	006	·35197	291
20° 20′	·17933	150	·08895	073	·01595	026	·00395	006	·35488	291
20° 30′	·18083	150	·08969	073	·01622	027	·00401	006	·35779	291
20° 40′	·18233	150	·09042	073	·01649	027	·00408	006	·36070	291
20° 50′	·18383	150	·09116	073	·01676	027	·00414	006	·36361	291
21° 00′	·18534	150	·09189	073	·01703	027	·00421	007	·36652	291
21° 10′	·18684	150	·09262	073	·01730	027	·00428	007	·36942	291
21° 20′	·18835	151	·09335	073	·01758	028	·00435	007	·37234	291
21° 30′	·18985	151	·09409	073	·01786	028	·00441	007	·37524	291
21° 40′	·19136	151	·09482	073	·01814	028	·00448	007	·37815	291
21° 50′	·19287	151	·09556	073	·01843	029	·00455	007	·38106	291
22° 00′	·19438	151	·09629	073	·01872	029	·00462	007	·38397	291
22° 10′	·19589	151	·09703	073	·01900	029	·00469	007	·38688	291
22° 20′	·19740	151	·09776	073	·01930	029	·00477	007	·38979	291
22° 30′	·19891	151	·09849	073	·01959	029	·00483	007	·39270	291
22° 40′	·20042	151	·09922	073	·01989	030	·00491	007	·39561	291
22° 50′	·20194	151	·09996	073	·02018	030	·00498	007	·39852	291
23° 00′	·20345	152	·10069	073	·02049	030	·00506	007	·40143	291
23° 10′	·20497	152	·10143	073	·02079	030	·00513	007	·04433	291
23° 20′	·20648	152	·10216	073	·02109	030	·00520	007	·40724	291
23° 30′	·20800	152	·10290	073	·02140	031	·00527	007	·41015	291
23° 40′	·20952	152	·10363	073	·24171	031	·00535	008	·41306	291
23° 50′	·21104	152	·10437	073	·02202	031	·00543	008	·41597	291

TABLE 1—(*continued*).

Deflection Angle B A D.	Tangents A D and A C.	Difference.	Sub-tangents D F and F E.	Difference.	Secant—Rad. A E.	Difference.	Sub-Secant—Rad. F G.	Difference.	Length of Curve D G E C.	Difference.
(a)	(b)		(c)		(d)		(e)		(f)	
24° 00′	·21256	152	·10510	074	·02234	032	·00551	008	·41888	291
24° 10′	·21408	152	·10584	074	·02266	032	·00558	008	·42179	291
24° 20′	·21560	152	·10657	074	·02298	032	·00566	008	·42470	291
24° 30′	·21712	152	·10731	074	·02330	032	·00574	008	·42761	291
24° 40′	·21864	152	·10805	074	·02362	032	·00582	008	·43051	291
24° 50′	·22017	152	·10878	074	·02395	033	·00589	008	·43342	291
25° 00′	·22169	153	·10952	074	·02428	033	·00598	008	·43633	291
25° 10′	·22322	153	·11026	074	·02461	033	·00605	008	·43924	291
25° 20′	·22475	153	·11099	074	·02494	033	·00614	008	·44215	291
25° 30′	·22627	153	·11173	074	·02528	034	·00622	008	·44506	291
25° 40′	·22780	153	·11246	074	·02562	034	·00630	008	·44797	291
25° 50′	·22933	153	·11320	074	·02596	034	·00638	008	·45088	291
26° 00′	·23087	153	·11393	074	·02630	034	·00647	008	·45379	291
26° 10′	·23240	153	·11467	074	·02665	035	·00655	008	·45669	291
26° 20′	·23393	153	·11541	074	·02700	035	·00664	009	·45960	291
26° 30′	·23547	153	·11615	074	·02735	035	·00672	009	·46251	291
26° 40′	·23700	153	·11688	074	·02770	035	·00681	009	·46542	291
26° 50′	·23854	154	·11762	074	·02806	036	·00689	009	·46833	291
27° 00′	·24008	154	·11836	074	·02841	036	·00698	009	·47124	291
27° 10′	·24162	154	·11910	074	·02877	036	·00706	009	·47415	291
27° 20′	·24316	154	·11983	074	·02914	036	·00715	009	·47706	291
27° 30′	·24470	154	·12057	074	·02950	036	·00724	009	·47997	291
27° 40′	·24624	154	·12131	074	·02987	037	·00733	009	·48287	291
27° 50′	·24778	154	·12205	074	·03024	037	·00742	009	·48578	291
28° 00′	·24933	154	·12278	074	·03061	037	·00751	009	·48869	291
28° 10′	·25087	154	·12352	074	·03099	037	·00760	009	·49160	291
28° 20′	·25242	155	·12426	074	·03137	038	·00769	009	·49451	291
28° 30′	·25397	155	·12500	074	·03174	038	·00778	009	·49742	291
28° 40′	·25552	155	·12574	074	·03213	038	·00787	009	·50033	291
28° 50′	·25707	155	·12648	074	·03251	038	·00796	009	·50324	291
29° 00′	·25862	155	·12722	074	·03290	039	·00806	009	·50615	291
29° 10′	·26017	155	·12796	074	·03329	039	·00815	009	·50905	291
29° 20′	·26172	155	·12869	074	·03368	039	·00825	009	·51196	291
29° 30′	·26328	155	·12943	074	·03408	039	·00834	009	·51487	291
29° 40′	·26483	155	·13017	074	·03447	040	·00844	009	·51778	291
29° 50′	·26639	156	·13091	074	·03487	040	·00853	009	·52069	291

TABLE 1—(*continued*).

Deflection Angle B A D.	Tangents A D and A C.	Difference.	Sub-tangents D F and F E.	Difference.	Secant—Rad. A E.	Difference.	Sub-Secant—Radius F G.	Difference.	Length of Curve D G E C.	Difference.
(a)	(b)		(c)		(d)		(e)		(f)	
30° 00′	·26795	156	·13165	074	·03528	040	·00863	010	·52360	291
30° 10′	·26951	156	·13239	074	·03568	040	·00873	010	·52651	291
30° 20′	·27107	156	·13313	074	·03609	041	·00882	010	·52942	291
30° 30′	·27263	156	·13387	074	·03650	041	·00892	010	·53233	291
30° 40′	·27419	156	·13461	074	·03691	041	·00902	010	·53523	291
30° 50′	·27576	156	·13535	074	·03732	041	·00912	010	·54814	291
31° 00′	·27732	156	·13609	074	·03774	042	·00922	010	·54105	291
31° 10′	·27889	157	·13684	074	·03816	042	·00932	010	·54396	291
31° 20′	·28046	157	·13757	074	·03858	042	·00942	010	·54687	291
31° 30′	·28203	157	·13832	074	·03901	043	·00952	010	·54978	291
21° 40′	·28360	157	·13906	074	·03944	043	·00962	010	·55269	291
31° 50′	·28517	157	·13980	074	·03987	043	·00972	010	·55560	291
32° 00′	·28674	157	·14054	074	·04030	043	·00983	010	·55851	291
32° 10′	·28832	157	·14128	074	·04073	043	·00993	010	·56141	291
32° 20′	·28990	158	·14202	074	·04117	044	·01003	010	·56432	291
32° 30′	·29147	158	·14277	074	·04161	044	·01014	010	·56723	291
32° 40′	·29305	158	·14351	074	·04205	044	·01024	010	·57014	291
32° 50′	·29463	158	·14425	074	·04250	045	·01035	010	·57305	291
33° 00′	·29621	158	·14499	074	·04295	045	·01046	010	·57596	291
33° 10′	·29780	158	·14574	074	·04340	045	·01056	010	·57887	291
33° 20′	·29938	158	·14648	074	·04385	045	·01067	011	·58178	291
33° 30′	·30096	158	·14722	074	·04431	046	·01078	011	·58468	291
33° 40′	·30255	159	·14796	074	·04477	046	·01089	011	·58759	291
33° 50′	·30414	159	·14871	074	·04523	046	·01100	011	·59050	291
34° 00′	·30573	159	·14945	074	·04569	046	·01111	011	·59341	291
34° 10′	·30732	159	·15019	074	·04616	047	·01121	011	·59632	291
34° 20′	·30891	159	·15094	074	·04663	047	·01133	011	·59923	291
34° 30′	·31051	159	·15168	074	·04710	047	·01144	011	·60214	291
34° 40′	·31210	159	·15243	074	·04757	047	·01155	011	·60505	291
34° 50′	·31370	160	·15317	074	·04805	048	·01166	011	·60796	291
35° 00′	·31530	160	·15391	074	·04853	048	·01177	011	·61087	291
35° 10′	·31690	160	·15466	074	·04901	048	·01189	011	·61377	291
35° 20′	·31850	160	·15540	074	·04950	048	·01200	011	·61668	291
35° 30′	·32010	160	·15616	074	·04998	048	·01211	011	·61959	291
35° 40′	·32171	160	·15689	074	·05047	049	·01223	011	·62250	291
35° 50′	·32331	160	·15764	074	·05097	049	·01234	011	·62541	291

TABLE 1—(*continued*)

Deflection Angle B A D.	Tangents A D and A C.	Difference.	Sub-tangents D F and F E.	Difference.	Secant—Rad. A E.	Difference.	Sub-Secant—Radius F G.	Difference.	Length of Curve D G E C.	Difference.
(a)	(b)		(c)		(d)		(e)		(f)	
36° 00′	·32492	161	·15838	074	·05146	049	·01246	012	·62832	291
36° 10′	·32653	161	·15913	075	·05196	050	·01258	012	·63123	291
36° 20′	·32814	161	·15987	075	·05246	050	·01270	012	·63414	291
36° 30′	·32975	161	·16062	075	·05296	050	·01281	012	·63705	291
36° 40′	·33136	161	·16137	075	·05347	051	·01294	012	·63995	291
36° 50′	·33298	161	·16211	075	·05398	051	·01305	012	·64286	291
37° 00′	·33459	161	·16286	075	·05449	051	·01317	012	·64577	291
37° 10′	·33621	162	·16361	075	·05501	052	·01329	012	·64868	291
37° 20′	·33783	162	·16435	075	·05552	052	·01342	012	·65159	291
37° 30′	·33945	162	·16510	075	·05604	052	·01353	012	·65450	291
37° 40′	·34108	162	·16585	075	·05657	052	·01366	012	·65741	291
37° 50′	·34270	162	·16659	075	·05709	052	·01378	012	·66032	291
38° 00′	·34433	163	·16734	075	·05762	053	·01390	012	·66323	291
38° 10′	·34595	163	·16809	075	·05815	053	·01402	012	·66613	291
38° 20′	·34758	163	·16884	075	·05868	053	·01415	012	·66904	291
38° 30′	·34921	163	·16959	075	·05922	054	·01427	012	·67195	291
38° 40′	·35085	163	·17033	075	·05976	054	·01440	012	·67486	291
38° 50′	·35248	163	·17108	075	·06030	054	·01452	012	·67777	291
39° 00′	·35412	164	·17183	075	·06085	055	·01465	013	·68068	291
39° 10′	·35576	164	·17258	075	·06139	055	·01478	013	·68359	291
39° 20′	·35739	164	·17333	075	·06195	055	·01491	013	·68650	291
39° 30′	·35904	164	·17408	075	·06250	055	·01503	013	·68941	291
39° 40′	·36068	164	·17483	075	·06305	055	·01517	013	·69231	291
39° 50′	·36232	164	·17558	075	·06361	056	·01529	013	·69522	291
40° 00′	·36397	165	·17633	075	·06418	056	·01543	013	·69813	291
40° 10′	·36562	165	·17708	075	·06474	056	·01555	013	·70104	291
40° 20′	·36727	165	·17783	075	·06531	057	·01569	013	·70395	291
40° 30′	·36892	165	·17858	075	·06588	057	·01582	013	·70686	291
40° 40′	·37057	165	·17933	075	·06645	057	·01595	013	·70977	291
40° 50′	·37233	165	·18008	075	·06703	058	·01609	013	·71268	291
41° 00′	·37388	166	·18038	075	·06761	058	·01622	013	·71558	291
41° 10′	·37554	166	·18158	075	·06819	058	·01635	013	·71849	291
41° 20′	·37720	166	·18233	075	·06878	059	·01649	013	·72140	291
41° 30′	·37887	166	·18308	075	·06936	059	·01662	013	·72431	291
41° 40′	·38053	166	·18383	075	·06995	059	·01676	014	·72722	291
41° 50′	·38220	166	·18459	075	·07055	059	·01690	014	·73013	291

TABLE 1—(*continued*).

Deflection Angle B A D.	Tangents A D and A C.	Difference.	Sub-tangents D F and F E.	Difference.	Secant—Rad. A E	Difference.	Sub-Secant—Rad. F G.	Difference.	Length of Curve D G E C.	Difference.
(a)	(b)		(c)		(d)		(e)		(f)	
42° 00′	·38386	167	·18534	075	·07114	060	·01703	014	·73304	291
42° 10′	·38553	167	·18609	075	·07174	060	·01717	014	·73595	291
42° 20′	·38720	167	·18684	075	·07235	060	·01730	014	·73886	291
42° 30′	·38888	167	·18760	075	·07295	060	·01745	014	·74176	291
42° 40′	·39055	167	·18835	075	·07356	061	·01758	014	·74467	291
42° 50′	·39233	168	·18910	075	·07417	061	·01772	014	·74758	291
43° 00′	·39391	168	·18985	075	·07479	061	·01786	014	·75049	291
43° 10′	·39559	168	·19061	075	·07540	061	·01800	014	·75340	291
43° 20′	·39727	168	·19136	075	·07602	062	·01814	014	·75631	291
43° 30′	·39896	168	·19212	075	·07665	062	·01829	014	·75922	291
43° 40′	·40065	169	·19287	075	·07727	062	·01843	014	·76213	291
43° 50′	·40233	169	·19362	075	·07799	063	·01857	014	·76504	291
44° 00′	·40403	169	·19438	075	·07853	063	·01872	014	·76794	291
44° 10′	·40572	169	·19513	075	·07917	064	·01886	014	·77085	291
44° 20′	·40741	169	·19589	075	·07981	064	·01900	014	·77376	291
44° 30′	·40911	170	·19664	075	·08045	064	·01915	015	·77667	291
44° 40′	·41081	170	·19740	075	·08109	064	·01930	015	·77958	291
44° 50′	·41251	170	·19815	075	·08174	065	·01944	015	·78249	291
45° 00′	·41421	170	·19891	076	·08239	065	·01959	015	·78540	291
45° 10′	·41592	170	·19967	076	·08304	065	·01974	015	·78831	291
45° 20′	·41762	170	·20042	076	·08370	066	·01989	015	·79122	291
45° 30′	·41933	171	·20118	076	·08436	066	·02004	015	·79412	291
45° 40′	·42105	171	·20194	076	·08502	066	·02018	015	·79703	291
45° 50′	·42276	171	·20269	076	·08569	067	·02033	015	·79994	291
46° 00′	·42447	171	·20345	076	·08636	067	·02049	015	·80285	291
46° 10′	·42619	172	·20421	076	·08703	067	·02064	015	·80576	291
46° 20′	·42791	172	·20497	076	·08771	068	·02079	015	·80867	291
46° 30′	·42963	172	·20572	076	·08839	068	·02094	015	·81158	291
46° 40′	·43136	172	·20648	076	·08907	068	·02109	015	·81449	291
46° 50′	·43308	172	·20724	076	·08975	068	·02125	015	·81740	291
47° 00′	·43841	173	·20800	076	·09044	069	·02140	015	·82030	291
47° 10′	·43654	173	·20876	076	·09113	069	·02156	016	·82321	291
47° 20′	·43827	173	·20952	076	·09183	069	·02171	016	·82612	291
47° 30′	·44001	173	·21027	076	·09252	070	·02187	016	·82903	291
47° 40′	·44175	174	·21104	076	·09322	070	·02202	016	·83194	291
47° 50′	·44349	174	·21179	076	·09393	070	·02218	016	·83485	291

TABLE 1—(*continued*).

Deflection Angle B A D.	Tangents A D and A C.	Difference.	Sub-tangents D F and F E.	Difference.	Secant—Rad, A E.	Difference.	Sub-Secant—Radius F G.	Difference.	Length of Curve D G E C.	Difference.
(a)	(b)		(c)		(d)		(e)		(f)	
48° 00′	·44523	174	·21256	076	·09464	071	·02234	016	·83776	291
48° 10′	·44697	174	·21331	076	·09535	071	·02250	016	·84067	291
48° 20′	·44872	175	·21408	076	·09606	071	·02266	016	·84358	291
48° 30′	·45047	175	·21483	076	·09678	072	·02281	016	·84648	291
48° 40	·45222	175	·21560	076	·09750	072	·02298	016	·84939	291
48° 50′	·45397	175	·21636	076	·09822	072	·02313	016	·85230	291
49° 00′	·45573	176	·21712	076	·09895	073	·02330	016	·85521	291
49° 10′	·45748	176	·21788	076	·09968	073	·02346	016	·85812	291
49° 20′	·45924	176	·21864	076	·10041	073	·02362	016	·86103	291
49° 30′	·46101	176	·21940	076	·10115	074	·02378	016	·86394	291
49° 40′	·46277	176	·22017	076	·10189	074	·02395	016	·86685	291
49° 50′	·46454	177	·22093	076	·10263	074	·02411	016	·86976	291
50° 00′	·46631	177	·22169	076	·10338	075	·02428	017	·87266	291
50° 10′	·46808	177	·22245	076	·10413	075	·02444	017	·87557	291
50° 20′	·46985	177	·22322	076	·10488	075	·02461	017	·87848	291
50° 30′	·47163	178	·22398	076	·10564	076	·02477	017	·88139	291
50° 40′	·47341	178	·22475	076	·10640	076	·02494	017	·88430	291
50° 50′	·47519	178	·22551	076	·10716	076	·02511	017	·88721	291
51° 00′	·47697	178	·22628	076	·10793	077	·02528	017	·89012	291
51° 10′	·47876	179	·22704	076	·10870	077	·02545	017	·89303	291
51° 20′	·48055	179	·22781	077	·10947	077	·02562	017	·89594	291
51° 30′	·48234	179	·22857	077	·11025	078	·02578	017	·89884	291
51° 40′	·48414	179	·22934	077	·11103	078	·02596	017	·90175	291
51° 50′	·48593	179	·23010	077	·11181	078	·02613	017	·90466	291
52° 00′	·48773	180	·23087	077	·11260	079	·02630	017	·90757	291
52° 10′	·48953	180	·23163	077	·11339	079	·02647	017	·91048	291
52° 20′	·49134	180	·23240	077	·11419	079	·02665	017	·91339	291
52° 30′	·49314	180	·23316	077	·11498	080	·02682	017	·91630	291
52° 40′	·49495	181	·23393	077	·11579	080	·02700	017	·91921	291
52° 50′	·49677	181	·23470	077	·11659	080	·02717	017	·92212	291
53° 00′	·49858	181	·23547	077	·11740	081	·02735	018	·92502	291
53° 10′	·50040	182	·23623	077	·11821	081	·02753	018	·92793	291
53° 20′	·50222	182	·23700	077	·11903	082	·02770	018	·93084	291
53° 30′	·50404	182	·23777	077	·11985	082	·02787	018	·93375	291
53° 40′	·50587	183	·23854	077	·12067	082	·02806	018	·93666	291
53° 50′	·50769	183	·23931	077	·12150	083	·02824	018	·93957	291

TABLE 1—(*continued*).

Deflection Angle B A D.	Tangents A D and A C.	Difference.	Sub-tangents D F and F E.	Difference.	Secant—Rad. A E.	Difference.	Sub-Secant—Radius F G.	Difference.	Length of Curve D G E C.	Difference.
(a)	(b)		(c)		(d)		(e)		(f)	
54° 00′	·50952	183	·24008	077	·12233	083	·02841	018	·94248	291
54° 10′	·51136	184	·24084	077	·12316	083	·02860	018	·94539	291
54° 20′	·51319	184	·24162	077	·12400	084	·02877	018	·94830	291
54° 30′	·51503	184	·24238	077	·12484	084	·02896	018	·95120	291
54° 40′	·51687	184	·24316	077	·12568	084	·02914	018	·95411	291
54° 50′	·51872	185	·24392	077	·12653	085	·02932	018	·95702	291
55° 00′	·52057	185	·24470	077	·12738	085	·02950	018	·95993	291
55° 10′	·52242	185	·24546	077	·12824	086	·02969	018	·96284	291
55° 20′	·52427	185	·24624	077	·12910	086	·02987	018	·96575	291
55° 30′	·52612	185	·24701	077	·12996	086	·03006	018	·96866	291
55° 40′	·52798	186	·24778	077	·13082	087	·03024	018	·97157	291
55° 50′	·52984	186	·24855	077	·13170	087	·03043	018	·97448	291
56° 00′	·53171	186	·24933	077	·13257	087	·03061	018	·97738	291
56° 10′	·53358	187	·25010	077	·13345	088	·03080	019	·98029	291
56° 20′	·53545	187	·25087	077	·13433	088	·03099	019	·98320	291
56° 30′	·53732	187	·25164	077	·13521	088	·03118	019	·98611	291
56° 40′	·53919	187	·25242	077	·13610	089	·03137	019	·98902	291
56° 50′	·54107	188	·25319	077	·13700	089	·03156	019	·99193	291
57° 00′	·54295	188	·25397	077	·13789	089	·03174	019	·99484	291
57° 10′	·54484	188	·25474	077	·13879	090	·03194	019	·99775	291
57° 20′	·54673	189	·25552	077	·13970	090	·03213	019	1·00066	291
57° 30′	·54862	189	·25629	077	·14061	091	·03232	019	1·00356	291
57° 40′	·55051	189	·25707	078	·14152	091	·03251	019	1·00647	291
57° 50′	·55241	190	·25784	078	·14243	091	·03271	019	1·00938	291
58° 00′	·55431	190	·25862	078	·14335	092	·03290	019	1·01229	291
58° 10′	·55621	190	·25939	078	·14428	092	·03309	019	1·01520	291
58° 20′	·55812	191	·26017	078	·14520	092	·03329	019	1·01811	291
58° 30′	·56003	191	·26094	078	·14614	093	·03349	019	1·02012	291
58° 40′	·56194	191	·26172	078	·14707	093	·03368	019	1·02393	291
58° 50′	·56385	192	·26250	078	·14801	094	·03388	020	1·02684	291
59° 00′	·56577	192	·26328	078	·14895	094	·03408	020	1·02974	291
59° 10′	·56769	192	·26406	078	·14990	095	·03427	020	1·03265	291
59° 20′	·56962	193	·26483	078	·15085	095	·03447	020	1·03556	291
59° 30′	·57155	193	·26562	078	·15181	096	·03467	020	1·03847	291
59° 40′	·57348	193	·26639	078	·15277	096	·03487	020	1·04138	291
59° 50′	·57541	193	·26717	078	·15373	096	·03507	020	1·04429	291

TABLE 1—(*continued*).

Deflection Angle B A D.	Tangents A D and A C.	Difference.	Sub-tangents D F and F E.	Difference	Secant—Rad. A E.	Difference.	Sub-Secant—Rad, F G.	Difference.	Length of Curve D G E C.	Difference
(a)	(b)		(c)		(d)		(e)		(f)	
60° 00′	·57735	194	·26795	078	·15470	097	·03528	020	1·04720	291
60° 10′	·57929	194	·26873	078	·15567	097	·03548	020	1·05011	291
60° 20′	·58123	194	·26951	078	·15665	098	·03568	020	1·05302	291
60° 30′	·58318	195	·27029	078	·15763	098	·03588	020	1·05592	291
60° 40′	·58513	195	·27107	078	·15861	098	·03609	020	1·05883	291
60° 50′	·58709	195	·27185	078	·15960	099	·03629	020	1·06174	291
61° 00′	·58904	196	·27263	078	·16059	099	·03650	020	1·06465	291
61° 10′	·59100	196	·27342	078	·16159	100	·03670	020	1·06756	291
61° 20′	·59297	196	·27419	078	·16259	100	·03691	021	1·07047	291
61° 30′	·59494	197	·27498	078	·16359	100	·03711	021	1·07338	291
61° 40′	·59691	197	·27576	078	·16460	101	·03732	021	1·07629	291
61° 50′	·59888	197	·27654	078	·16562	101	·03753	021	1·07920	291
62° 00′	·60086	198	·27732	078	·16663	102	·03774	021	1·08210	291
62° 10′	·60284	198	·27811	078	·16765	102	·03795	021	1·08501	291
62° 20′	·60483	199	·27889	078	·16868	103	·03816	021	1·08792	291
62° 30′	·60681	199	·27968	078	·16971	103	·03837	021	1·09083	291
62° 40′	·60881	199	·28046	078	·17074	103	·03858	021	1·09374	291
62° 50′	·61080	199	·28125	078	·17178	104	·03880	021	1·09665	291
63° 00′	·61280	190	·28203	078	·17283	105	·03901	021	1·09956	291
63° 10′	·61480	190	·28282	078	·17387	105	·03922	021	1·10247	291
63° 20′	·61681	191	·28360	078	·17493	106	·03944	021	1·10538	291
63° 30′	·61882	191	·28439	079	·17598	106	·03965	021	1·10828	291
63° 40′	·62083	191	·28517	079	·17704	106	·03987	021	1·11119	291
63° 50′	·62285	192	·28596	079	·17811	107	·04008	021	1·11410	291
64° 00′	·62487	192	·28674	079	·17918	107	·04030	022	1·11701	291
64° 10′	·62689	192	·28753	079	·18025	107	·04051	022	1·11992	291
64° 20′	·62892	193	·28832	079	·18133	108	·04073	022	1·12283	291
64° 30′	·63095	193	·28911	079	·18241	108	·04095	022	1·12574	291
64° 40′	·63299	194	·28990	079	·18350	109	·04117	022	1·12865	291
64° 50′	·63503	194	·29069	079	·18459	109	·04139	022	1·13156	291
65° 00′	·63707	194	·29147	079	·18569	110	·04161	022	1·13446	291
65° 10′	·63912	195	·29226	079	·18679	110	·04183	022	1·13737	291
65° 20′	·64117	195	·29305	079	·18789	110	·04205	022	1·14028	291
65° 30′	·64322	195	·29384	079	·18900	111	·04227	022	1·14319	291
65° 40′	·64528	196	·29463	079	·19012	111	·04250	022	1·14610	291
65° 50′	·64734	196	·29542	079	·19124	112	·04272	022	1·14901	291

TABLE 1—(*continued*).

Deflection Angle B A D.	Tangents A D and A C.	Difference.	Sub-tangents D F and F E.	Difference.	Secant—Rad. A E.	Difference.	Sub-Secant—Radius F G.	Difference.	Length of Curve D G E C.	Difference.
(a)	(b)		(c)		(d)		(e)		(f)	
66° 00′	·64941	197	·29621	079	·19236	112	·04295	022	1 ·15192	291
66° 10′	·65148	197	·29701	079	·19349	113	·04317	022	1 ·15483	291
66° 20′	·65355	197	·29780	079	·19462	113	·04340	022	1 ·15774	291
66° 30′	·65563	198	·29859	079	·19576	114	·04362	022	1 ·16064	291
66° 40′	·65771	198	·29938	079	·19690	114	·04385	023	1 ·16355	291
66° 50′	·65980	199	·30017	079	·19805	115	·04407	023	1 ·16646	291
67° 00′	·66189	199	·30096	079	·19920	115	·04431	023	1 ·16937	291
67° 10′	·66398	199	·30176	079	·20036	116	·04454	023	1 ·17228	291
67° 20′	·66608	200	·30255	079	·20152	116	·04477	023	1 ·17519	291
67° 30′	·66818	200	·20335	079	·20269	117	·04500	023	1 ·17810	291
67° 40′	·67028	200	·30414	079	·20386	117	·04523	023	1 ·18101	291
67° 50′	·67239	201	·30494	079	·20504	118	·04546	023	1 ·18392	291
68° 00′	·67451	201	·30573	080	·20622	118	·04569	023	1 ·18682	291
68° 10′	·67663	202	·30653	080	·20740	119	·04593	023	1 ·18973	291
68° 20′	·67875	202	·30732	080	·20859	119	·04616	023	1 ·19264	291
68° 30′	·68087	202	·30812	080	·20979	120	·04639	023	1 ·19555	291
68° 40′	·68301	203	·30891	080	·21099	120	·04663	023	1 ·19846	291
68° 50′	·68514	203	·30971	080	·21220	121	·04686	023	1 ·20137	291
69° 00′	·68728	204	·31051	080	·21341	121	·04710	024	1 ·20428	291
69° 10′	·68942	204	·31131	080	·21462	122	·04734	024	1 ·20719	291
69° 20′	·69157	205	·31210	080	·21584	122	·04757	024	1 ·21009	291
69° 30′	·69372	205	·31290	080	·21707	123	·04781	024	1 ·21300	291
69° 40′	·69588	206	·31370	080	·21830	123	·04805	024	1 ·21591	291
69° 50′	·69804	206	·31450	080	·21953	123	·04829	024	1 ·21882	291
70° 00′	·70021	207	·31530	080	·22077	124	·04853	024	1 ·22173	291

TABLE II. TANGENTIAL ANGLES.

Arc.	Radii.							
Chains.	5 chains.	6 chains	7 chains.	8 chains.	9 chains.	10 chains.	11 chains.	12 chains.
½	2° 51′·9	2° 23′·2	2° 2′·8	1° 47′·4	1° 35′·5	1° 25′·9	1° 18′·1	1° 11′·6
1	5° 43′·8	4° 46′·5	4° 5′·6	3° 34′·9	3° 11′·0	2° 51′·9	2° 26′·3	2° 23′·2
1½	8° 35′·7	7° 9′·7	6° 8′·3	5° 22′·3	4° 46′·5	4° 17′·8	3° 54′·4	3° 34′·9
2	11° 27′·5	9° 33′·0	8° 11′·1	7° 9′·7	6° 22′·0	5° 43′·8	5° 12′·5	4° 46′·5
2½	14° 19′·4	11° 56′·2	10° 13′·9	8° 57′·1	7° 57′·5	7° 9′·7	6° 30′·7	5° 58′·1
3	17° 11′·3	14° 19′·4	12° 16′·7	10° 44′·6	9° 33′·0	8° 35′·7	7° 48′·8	7° 9′·7
3½	20° 3′·2	16° 42′·7	14° 19′·4	12° 32′·0	11° 8′·4	10° 1′·6	9° 6′·9	8° 21′·3
4	22° 55′·1	19° 5′·9	16° 22′·2	14° 19′·4	12° 43′·9	11° 27′·5	10° 25′·0	9° 33′·0
4½	25° 47′·0	21° 29′·1	18° 25′·0	16° 06′·8	14° 19′·4	12° 53′·5	11° 43′·2	10° 44′·6
5	28° 38′·8	23° 52′·4	20° 27′·8	17° 54′·2	15° 55′·0	14° 19′·4	13° 1′·3	11° 56′·2
5½	31° 30′·7	26° 15′·6	22° 30′·6	19° 41′·6	17° 30′·5	15° 45′·3	14° 19′·4	13° 7′·8
6	34° 22′·6	28° 38′·8	24° 33′·4	21° 29′·2	19° 06′·4	17° 11′·4	15° 37′·6	14° 19′·4
6½	37° 14′·5	31° 02′·0	26° 36′·2	23° 16′·6	20° 41′·5	18° 37′·3	16° 55′·7	15° 31′·0
7	40° 6′·4	33° 25′·4	28° 38′·9	25° 04′·0	22° 16′·8	20° 03′·2	18° 13′·8	16° 42′·6
7½	42° 58′·3	35° 48′·6	30° 41′·7	26° 51′·4	23° 52′·3	21° 29′·1	19° 31′·9	17° 54′·2
8	45° 50′·2	38° 11′·8	32° 44′·4	28° 38′·8	25° 27′·8	22° 55′·0	20° 50′·0	19° 06′·0
8½	48° 42′·1	40° 35′·2	34° 47′·2	30° 26′·2	27° 03′·3	24° 20′·9	22° 08′·1	20° 17′·6
9	51° 34′·0	42° 58′·2	36° 50′·0	32° 13′·6	28° 38′·8	25° 47′·0	23° 26′·4	21° 29′·2
9½	54° 25′·9	45° 21′·4	38° 52′·8	34° 01′·0	30° 14′·3	27° 12′·9	24° 44′·5	22° 40′·8
10	57° 17′·6	47° 44′·8	40° 55′·6	35° 48′·4	31° 50′·0	28° 38′·8	26° 02′·6	23° 52′·4

TABLE II.—Continued

Arc.	Radii.							
Chains.	13 chains.	14 chains.	15 chains.	16 chains.	17 chains.	18 chains.	19 chains.	20 chains.
½	1° 6′·1	1° 1′·4	0° 57′·3	0° 53′·7	0° 50′·6	0° 47′·7	0° 45′·2	0° 43′·0
1	2° 12′·2	2° 2′·8	1° 47′·4	1° 47′·4	1° 41′·1	1° 35′·5	1° 30′·5	1° 25′·9
1½	3° 18′·3	3° 4′·2	2° 51′·9	2° 41′·1	2° 31′·7	2° 23′·2	2° 15′·7	2° 08′·9
2	4° 24′·4	4° 5′·6	3° 34′·9	3° 34′·9	3° 22′·2	3° 11′·0	3° 0′·9	2° 51′·9
2½	5° 30′·6	5° 6′·9	4° 46′·5	4° 28′·6	4° 12′·8	3° 58′·7	3° 46′·2	3° 34′·9
3	6° 36′·7	6° 8′·3	5° 43′·8	5° 22′·3	5° 3′·3	4° 46′·4	4° 31′·4	4° 17′·8
3½	7° 42′·8	7° 9′·7	6° 41′·1	6° 16′·0	5° 53′·9	5° 34′·2	5° 16′·6	5° 00′·8
4	8° 48′·9	8° 11′·1	7° 38′·4	7° 9′·7	6° 44′·4	6° 21′·9	6° 1′·9	5° 43′·8
4½	9° 55′·0	9° 12′·5	8° 35′·7	8° 3′·4	7° 35′·0	7° 9′·7	6° 47′·1	6° 26′·8
5	11° 1′·1	10° 13′·9	9° 33′·0	8° 57′·1	8° 25′·6	7° 57′·4	7° 32′·3	7° 9′·7
5½	12° 7′·2	11° 15′·3	10° 30′·3	9° 50′·9	9° 16′·1	8° 45′·2	8° 17′·6	7° 52′·7
6	13° 13′·3	12° 16′·7	11° 27′·6	10° 44′·6	10° 6′·7	9° 32′·9	9° 2′·8	8° 35′·7
6½	14° 19′·4	13° 18′·1	12° 24′·8	11° 38′·3	10° 57′·2	10° 20′·6	9° 48′·0	9° 18′·7
7	15° 25′·6	14° 19′·4	13° 22′·1	12° 32′·0	11° 47′·8	11° 8′·4	10° 33′·3	10° 1′·6
7½	16° 31′·7	15° 20′·8	14° 19′·4	13° 25′·7	12° 38′·3	11° 56′·1	11° 18′·5	10° 44′·6
8	17° 37′·8	16° 22′·2	15° 16′·7	14° 19′·4	13° 28′·9	12° 43′·9	12° 3′·7	11° 27′·6
8½	18° 43′·9	17° 23′·6	16° 14′·0	15° 13′·2	14° 19′·4	13° 31′·6	12° 49′·0	12° 10′·6
9	19° 50′·0	18° 25′·0	17° 11′·3	16° 6′·9	15° 10′·0	14° 19′·3	13° 34′·2	12° 53′·5
9½	20° 56′·1	19° 26′·4	18° 8′·6	17° 0′·6	16° 0′·5	15° 7′·1	14° 19′·4	13° 36′·5
10	22° 2′·2	20° 27′·8	19° 5′·9	17° 54′·3	16° 51′·1	15° 54′·8	15° 4′·7	14° 19′·4

TABLE II.—Continued

Arc.	Radii.							
Chains.	22 chains.	24 chains.	25 chains.	28 chains.	30 chains.	32 chains.	34 chains.	35 chains.
1	1° 18′·1	1° 11′·6	1° 8′·8	1° 1′·4	0° 57′·3	0° 53′·7	0° 50′·6	0° 49′·1
2	2° 26′·3	2° 23′·2	2° 17′·5	2° 2′·8	1° 54′·6	1° 47′·4	1° 41′·1	1° 38′·2
3	3° 54′·4	3° 34′·9	3° 26′·3	3° 4′·2	2° 51′·9	2° 41′·1	2° 31′·7	2° 27′·3
4	5° 12′·5	4° 46′·5	4° 35′·0	4° 5′·6	3° 49′·2	3° 34′·9	3° 22′·2	3° 16′·4
5	6° 30′·7	5° 58′·1	5° 43′·8	5° 6′·9	4° 46′·5	4° 28′·6	4° 12′·8	4° 5′·6
6	7° 48·8	7° 9′·7	6° 52′·5	6° 8′·3	5° 43°·8	5° 22′·3	5° 3′·3	4° 54′·7
7	9° 6′·9	8° 21′·3	8° 1′·3	7° 9′·7	6° 41′·1	6° 16′·0	5° 53′·9	5° 43′·8
8	10° 25′·0	9° 33′·0	9° 10′·0	8° 11′·1	7° 38′·4	7° 9′·7	6° 44′·4	6° 32′·9
9	11° 43′·2	10° 44′·6	10° 18′·8	9° 12′·5	8° 35′·7	8° 3′·4	7° 35′·0	7° 22′·0
10	13° 1′·3	11° 56′·2	11° 27′·6	10° 13′·9	9° 33′·0	8° 57′·1	8° 25′·6	8° 11′·1

Arc.	Radii.							
Chains.	36 chains.	38 chains.	40 chains.	44 chains.	45 chains.	48 chains	50 chains.	52 chains.
1	0° 47′·7	0° 45′·2	0° 43′·0	0° 39′·1	0° 38′·2	0° 35′·8	0° 34′·4	0° 33′·1
2	1° 35′·5	1° 30′·5	1° 25′·9	1° 18′·1	1° 16′·4	1° 11′·6	1° 8′·8	1° 6′·1
3	2° 23′·2	2° 15′·7	2° 8′·9	1° 57′·2	1° 54′·6	1° 47′·4	1° 43′·1	1° 39′·2
4	3° 11′·0	3° 0′·9	2° 51′·9	2° 26′·3	2° 32′·8	2° 23′·2	2° 17′·5	2° 12′·0
5	3° 58′·7	3° 46′·2	3° 34′·9	3° 15′·3	3° 11′·0	2° 59′·0	2° 51′·9	2° 45′·3
6	4° 46′·5	4° 31′·4	4° 17′·8	3° 54′·4	3° 49′·2	3° 34′·9	3° 26′·3	3° 18′·3
7	5° 34′·2	5° 16′·6	5° 0′·8	4° 33′·5	4° 27′·4	4° 10′·7	4° 0′·6	3° 51′·4
8	6° 22′·0	6° 1′·9	5° 43′·8	5° 12′·5	5° 5′·6	4° 46′·5	4° 35′·0	4° 24′·4
9	7° 9′·7	6° 47′·1	6° 26′·7	5° 51′·6	5° 43′·8	5° 22′·3	5° 9′·4	4° 57′·5
10	7° 57′·5	7° 32′·3	7° 9′·7	6° 30′·7	6° 22′·0	5° 58′·1	5° 43′·8	5° 30′·6

TABLE II.—Continued.

Arc.	Radii.							
Chains.	55 chains.	56 chains.	60 chains.	64 chains.	65 chains.	68 chains.	70 chains.	72 chains.
1	0° 31′·3	0° 30′·7	0° 28′·6	0° 26′·9	0° 26′·4	0° 25′·3	0° 24′·6	0° 23 ·9
2	1° 2′·5	1° 1′·4	0° 57′·3	0° 53′·7	0° 52′·9	0° 50′·6	0° 49′·1	0° 47′·7
3	1° 33′·8	1° 32′·1	1° 25′·9	1° 20′·6	1° 19′·3	1° 15′·8	1° 13′·7	1° 11′·6
4	2° 5′·0	2° 2′·8	1° 54′·6	1° 47′·4	1° 45′·8	1° 41′·1	1° 38′·2	1° 35′·5
5	2° 36′·3	2° 33′·5	2° 23′·2	2° 14′·3	2° 12′·2	2° 6′·4	2° 2′·8	1° 59′·4
6	3° 7′·5	3° 4′·2	2° 51′·9	2° 41′·1	2° 38′·7	2° 31′·7	2° 27′·3	2° 23′·2
7	3° 38′·8	3° 34′·9	3° 20′·5	3° 8′·0	3° 5′·1	2° 56′·9	2° 51′·9	2° 47′·1
8	4° 10′·0	4° 5′·6	3° 49′·2	3° 34′·9	3° 31′·6	3° 22′·2	3° 16′·4	3° 11′·0
9	4° 41′·3	4° 36′·2	4° 17′·8	4° 1′·7	3° 58′·0	3° 47′·5	3° 41′·0	3° 34′·9
10	5° 12′·5	5° 6′·9	4° 46′·5	4° 28′·6	4° 24′·4	4° 12′·8	4° 5′·6	3° 58′·7

Arc.	Radii.							
Chains.	75 chains.	76 chains.	80 chains.	85 chains.	90 chains.	95 chains.	100 chains.	110 chains.
1	0° 22′·9	0° 22′·6	0° 21′·5	0° 20′·2	0° 19′·1	0° 18′·1	0° 17′·2	0° 15′·6
2	0° 45′·8	0° 45′·2	0° 43′·0	0° 40′·4	0° 38′·2	0° 36′·2	0° 34′·4	0° 31′·3
3	1° 8′·8	1° 7′·9	1° 4′·5	1° 0′·7	0° 57′·3	0° 54′·3	0° 51′·6	0° 46′·9
4	1° 31′·7	1° 30′·5	1° 25′·9	1° 20′·9	1° 16′·4	1° 12′·4	1° 8′·8	1° 2·5
5	1° 54′·6	1° 53′·1	1° 47′·4	1° 41′·1	1° 35′·5	1° 30′·5	1° 25′·9	1° 18′·1
6	2° 17′·5	2° 15′·7	2° 8′·9	2° 1′·3	1° 54′·6	1° 48 ·6	1° 43′·1	1° 33′·8
7	2° 20′·4	2° 38′·3	2° 30′·4	2° 21′·6	2° 13′·7	2° 6′·7	2° 0′·3	1° 49′·4
8	3° 3′·3	3° 0′·9	2° 51′·9	2° 41′·8	2° 32′·8	2° 24′·7	2° 17′·5	2° 5 ·0
9	3° 26′·3	3° 23′·6	3° 13′·4	3° 2′·0	2° 51 ·9	2° 42′·8	2° 34′·7	2° 20 ·6
10	3° 49′·2	3° 46′·2	3° 34′·9	3° 22′·2	3° 11′·0	3° 0′·9	2° 51′·9	2° 36′·3

TABLE II.—Continued.

Arc.	Radii.							
Chains.	120 chains.	140 chains	150 chains.	160 chains.	180 chains.	200 chains.	220 chains.	240 chains.
1	0° 14′·3	0° 12′·3	0° 11′·6	0° 10′·7	0° 9′·6	0° 8′·6	0° 7′·8	0° 7′·2
2	0° 28·6	0° 24′·6	0° 22′·9	0° 21′·5	0° 19′·1	0° 17′·2	0° 15′·6	0° 14′·3
3	0° 43′·0	0° 36′·8	0° 34′·4	0° 32′·2	0° 28′·6	0° 25′·8	0° 23′·4	0° 21′·5
4	0° 57′·3	0° 49′·1	0° 45′·8	0° 43′·0	0° 38′·2	0° 34′·4	0° 31′·3	0° 28′·6
5	1° 11′·6	1° 1·4	0° 57′·3	0° 53′·7	0° 47′·7	0° 43·0	0° 39′·1	0° 35′·8
6	1° 25′·9	1° 13′·7	1° 8′·8	1° 4′·5	0° 57′·3	0° 51·6	0° 46′·9	0° 43′·0
7	1° 40·3	1° 25′·9	1° 20·2	1° 15′·2	1° 6′·8	1° 0′·2	0° 54′·7	0° 50′·1
8	1° 54′·6	1° 38′·2	1° 31′·7	1° 25′·9	1° 16′·4	1° 8′·8	1° 2′·5	0° 57′·3
9	2° 8′·9	1° 50′·5	1° 43′·1	1° 36′·7	1° 25′·9	1° 17′·4	1° 10·3	1° 4′·5
10	2° 23′·2	2° 2·8	1° 54′·6	1° 47′·4	1° 35′·5	1° 25′·9	1° 18′·1	1° 11′·6

Arc.	Radii.							
Chains.	250 chains.	260 chains.	280 chains.	300 chains.	350 chains.	400 chains.	450 chains.	500 chains.
1	0° 6′·9	0° 6′·6	0° 6′·1	0° 5′·7	0° 4·9	0° 4′·3	0° 3′·8	0° 3′·4
2	0° 13′·8	0° 13′·2	0° 12′·3	0° 11′·5	0° 9′·8	0° 8′·6	0° 7′·6	0° 6′·9
3	0° 20·6	0° 19′·8	0° 18′·4	0° 17′·2	0° 14′·7	0° 12′·9	0° 11′·5	0° 10′·3
4	0° 27′·5	0° 26′·4	0° 24′·6	0° 22′·9	0° 19′·6	0° 17·2	0° 15′·3	0° 13′·8
5	0° 34′·4	0° 33′·1	0° 30′·7	0° 28′·6	0° 24′·6	0° 21′·5	0° 19′·1	0° 17′·2
6	0° 41′·3	0° 39′·7	0° 36′·8	0° 34′·4	0° 29′·5	0° 25′·8	0° 22′·9	0° 20′·6
7	0° 48·1	0° 46·3	0° 43′·0	0° 40′·1	0° 34′·4	0° 30′·1	0° 26′·7	0° 24′·1
8	0° 55′·0	0° 52′·9	0° 49′·1	0° 45′·8	0° 39′·3	0° 34′·4	0° 30′·6	0° 27′·5
9	1° 1′·9	0° 59′·5	0° 55′·3	0° 51′·6	0° 44′·2	0° 38′·7	0° 34′·4	0° 30′·9
10	1° 8′·8	1° 6′·1	1° 1′·4	0° 57′·3	0° 49′·1	0° 43′·0	0° 38′·2	0° 34′·4

CALCULATION OF SWITCH AND CROSSING ANGLES.

The calculation of the necessary angles and distances for crossing work is now largely superseding the method of setting out on the ground, more especially where the work is not tied up by existing fittings, etc., the reason being that because of the greater accuracy attained, standardization of fittings, etc., is much simplified.

In considering this method of working it is first necessary to decide how the angles of the crossings are to be measured. There are several ways of doing this and since they all give slightly varying results it is necessary to choose one of them and adhere to it.

The one most generally used is that known as the centre method, in which the 6″ openings are measured at right angles to the centre line of the crossing, while the length is measured along the centre line A B (see Fig. 13). In this case the length of the crossing is represented trigonometrically by $\frac{1}{2}$ cot $\frac{1}{2}$ Θ, where Θ is the angle in degrees, etc.

Another method sometimes used is the right-angle method, in which the 6″ openings are measured at right-angles to the main line rail (Fig. 14). In this case the length of the crossing = cot Θ, where Θ is the angle in degrees, etc.

In the following the former method will be adopted.

As in setting out, the simple case of a turnout from the straight, in which the curve is tangential to the main line and the switches are placed at the 4½″ opening, will be taken first. Fig. 15.

The crossing lead will be A C = $\sqrt{(2R—g)g}$ where R is the radius of the outer lead rail and g the gauge. Also the switch lead A B = $\sqrt{(2R—d)d}$ where d = 4½″ opening = $\frac{3}{8}$ foot, but since the d in the bracket is so small compared with the other figures, it may be neglected, and if we insert the remaining d in figures we have A B = $\sqrt{2R \times \frac{3}{8}}$ = $\sqrt{\frac{3}{4}R}$. Hence we have the lead B C = $\sqrt{(2R—g)g}$ — $\sqrt{\frac{3}{4}R}$. Also N the crossing number or length in feet will be $N = \frac{\sqrt{R}}{\sqrt{2g}}$

In order to obtain a simple formula for use on the ground we may reduce the above equation to constants.

From the equation $N = \frac{\sqrt{R}}{\sqrt{2g}}$ we get $R = 2gN^2$ and putting this in the equation for the switch lead we have A B = $\sqrt{\frac{3}{4}R}$ = $\sqrt{\frac{3}{4}2gN^2}$ = $N\sqrt{1\frac{1}{2}g}$ = 2·66 N.

Fig. 13.

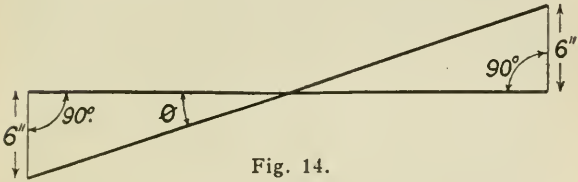


Fig. 14.

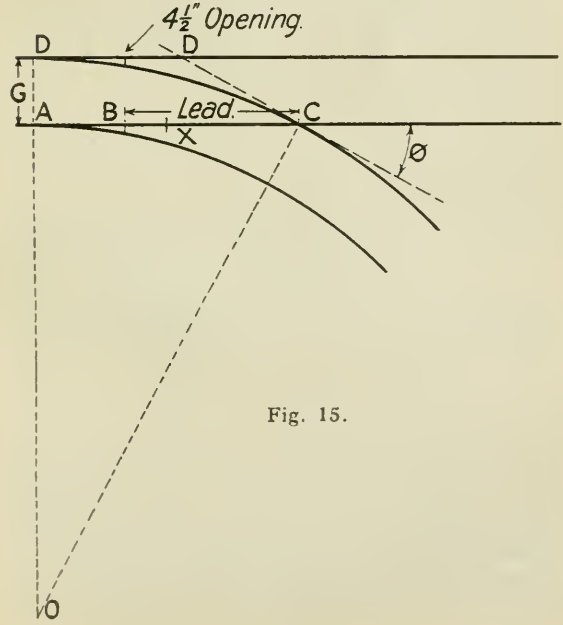


Fig. 15.

Also it may be shown that the crossing lead $=2gN$
$=9{\cdot}42N$

Therefore the lead $BC=9{\cdot}42N.—2{\cdot}46N=6{\cdot}76N.$

Main Line Curved.—Having obtained the above constant the lead for a curved main line can be readily found. It may be proved that if we bisect the crossing lead for the straight main line A C in x and with x as centre and Ax as radius construct a circle, so long as the crossing angle is constant, its intersection will always lie on the circumference of the circle, no matter what curve is given to the main line. It will therefore be sufficiently accurate to assume that the lead for any particular angle of crossing will be the same as for the straight main line, *viz.*, 6·76N.

It is now only necessary to calculate the value of N for the curved main line in order to find the lead.

Let r=radius of main line.
and R=radius of turnout.

Then for curves of similar flexure (Fig. 16)

$$N=\sqrt{\frac{rR}{2g\ (r-R)}} \qquad BC=6{\cdot}76\ N.$$

For curves of contrary flexure (Fig. 17)

$$N=\sqrt{\frac{rR}{2g\ (r+R)}} \qquad BC=6{\cdot}76N.$$

If it is required to find the radius of the turnout curve, this may be done as follows :—

Let R = radius of main line rail.
R_1 = radius of turnout from straight for required angle of crossing.
r = required radius of turnout.

For curves of contrary flexure $r=\dfrac{R\times R_1}{R-R_1}$

For curves of similar flexure $r=\dfrac{R\times R_1}{R+R_1}$

The foregoing formulæ are very convenient where leads only are concerned, but where other and more complicated fittings are involved it will be found more convenient to work trigonometrically as follows. Join D and C (Fig. 15) to the centre for the circular arc, then, since O C is at right angles to D C (which is tangential to the curve at the intersection of the crossing) and O A is at right angles to the main line, it is obvious that the angle A O C is equal to the angle at the intersection of the crossing θ.

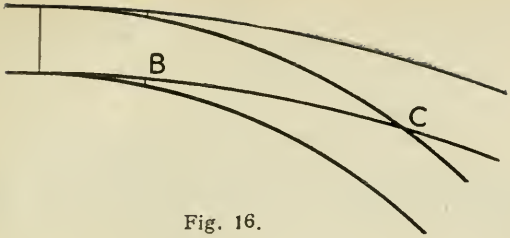


Fig. 16.

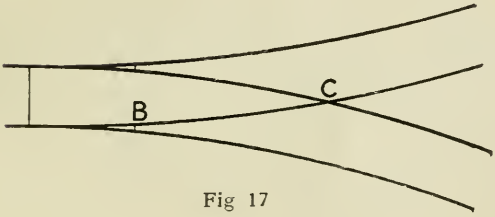


Fig 17

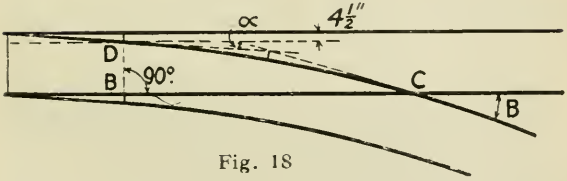


Fig. 18

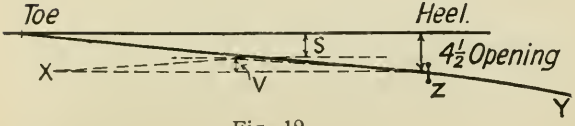


Fig. 19.

Now $\frac{R-g}{R} = \cos \theta$. ·. θ in degrees, etc., may be found from trigonometrical tables.

Crossing lead A C = R sin θ.

A B = $\sqrt{\frac{3}{4} R}$.

Length of circular rail = R arc θ.

Length of crossing angle in feet N = $\frac{1}{2}$ cot $\frac{1}{2}$ θ.

These may be worked very quickly by means of logarithms, but great accuracy is required, since the angles are very small, and six or seven figure tables should be used.

A table of curves and leads calculated on this method will be found on page 269.

Leads with Straight Switches and Turnout Curve Tangential at Heel.—In fast-running passenger junctions in which long straight switches are used, the leads obtained by the above methods will be found to vary by several feet from those in which the curves are calculated as being tangent to the heel of the switches.

For single leads with a given length of switch and crossing the following method is the simplest. Fig. 18.

Let α = angle of switch in degrees, etc.

and β = angle of crossing in degrees.

B D = 4′ 8½″—4½″ = 4·3333.

Then the lead B C = $4 \cdot 3333 \times \cot \frac{\alpha + \beta}{2}$

Where it is required to find the lead for a given radius tangential to the heel of the switch the following method may be used. (Fig. 19.)

It will be found that when the curve is tangential to the heel of a straight switch it probably never becomes tangential to the main line rail and in order that we may calculate the crossing angle it is necessary to find a new gauge with an imaginary rail to which the curve will become tangential. Fig. 18 represents a sketch of the switch, X Y being the circular arc tangential to the heel at Z, and s = the amount the main line rail must be shifted in order that the curve may become tangential. Now s = 4½″ less V, the versed sine on the curve for the length X Z.

$$\therefore \ s = \cdot 375 - R \text{ vers } \alpha$$

where R is the radius of the outer lead rail and α the angle of the switch in degrees, etc.

The reduced gauge G = g—s = 4·7083—s.

The lead and crossing angle may then be determined as before indicated, using G as the gauge in place of g, thus

Angle of crossing in degrees etc. $\cos C = \frac{R-G}{R}$ crossing $N = \frac{1}{2} \cot \frac{1}{2} C$ (Fig. 20).

Switch lead A D = R sin $\propto$ where $\propto$ = angle of switch in degrees.

Crossing lead $A_1C = R \sin C$.
Length of curved rail R × arc C.
Lead $D_1C = A_1C - A D$.

If it be required to obtain the angles of the further crossings E, F, H and K, it is necessary to repeat the operation using x as gauge in the case of E and F and y as gauge in the case of H and K, the distance F E being the difference between the crossing leads for the crossings E and F, and the distance E C the difference between the circular distance A C and the circular distance A E. R—g must be used as radius for the inner rail.

Where the leads and crossing angles are required for turnout curve tangential to the heel of a curved switch they may be found in the same way as for straight switches, using as the switch angle the angle between the main line rail and a straight line tangential at the heel of the switch.

In calculating leads, etc., for curved main line with turnout curve tangential to the heel of the switch for curves of similar flexure, it is assumed that the switches are made straight and afterwards curved to the radius of the main line rail, so that the switch angle remains the same as if it were straight.

Similar Flexure. (Fig. 21.)

$$\text{Shift } S = \frac{Rr}{(r-R)\,2n^2}$$

Where r = radius of main line (outer rail).
R = radius of turnout (outer rail).
n = angle of switch expressed in same way as crossing number, thus 1 in 80.

$$A D = 2sn^2.$$

$$\cos \frac{\Theta}{2} \sqrt{\frac{S\,[S-(r-R)]}{(r-g)\,R}}$$ from which Θ = crossing angle may be found.

$$\text{Where } S = \frac{R + (r-R) + (r-g)}{2}$$

Switch lead $A_1C = r$ arc B where $\sin B = \frac{R \sin \Theta}{r - R}$
Lead $= A_1C - A D$.

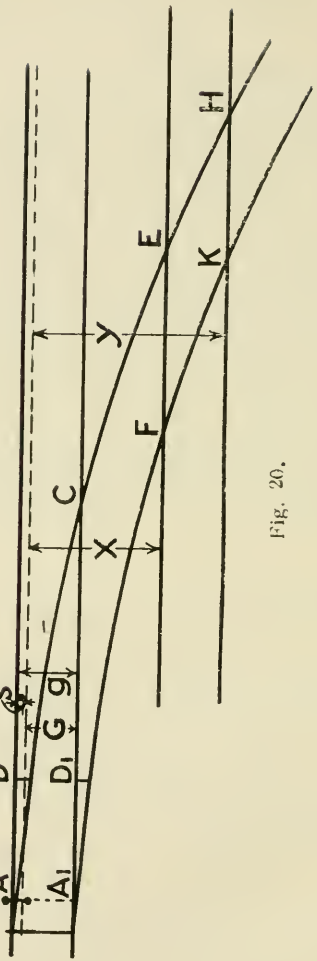


Fig. 20.

TABLE OF SWITCH LEADS AND DISTANCES FOR CURVES TANGENTIAL AT HEEL OF STRAIGHT SWITCHES (see Fig. 20). GAUGE 4′ 8½″

Radius of Outer Lead Rail in Chains.	Length of Straight Switch. ft.	Angle of Switch.	Shift. ft.	Reduced Gauge. ft.	Switch Lead. ft.	Crossing Lead. ft.	Angle of Crossing.	Crossing No. 1 in ft. ins.	Lead.
20	20′ 0″	1° 04′ 27″	·1428	4·5655	24·745	109·6805	4° 46′ 00″	12′ 0⅛″	84′ 11¼″
25	30′ 0″	0° 42′ 58″	·2463	4·4620	20·6272	121·2317	4° 12′ 52″	13′ 7″	100′ 7¼″
30	30′ 0′	0° 42′ 58″	·2275	4·4808	24·7480	133·1472	3° 51′ 21″	14′ 10¼″	108′ 4¾″
36	30′ 0″	0° 42′ 58″	·1896	4·5186	29·6744	146·5291	3° 32′ 05″	16′ 2½″	116′ 10¼″
40	30′ 0″	0° 42′ 58″	·1688	4·5394	32·9930	154·7450	3° 21′ 39″	17′ 0½″	121′ 9″

Gauge 4′ 8½″ = 4·70833 ft Log g = ·6728669

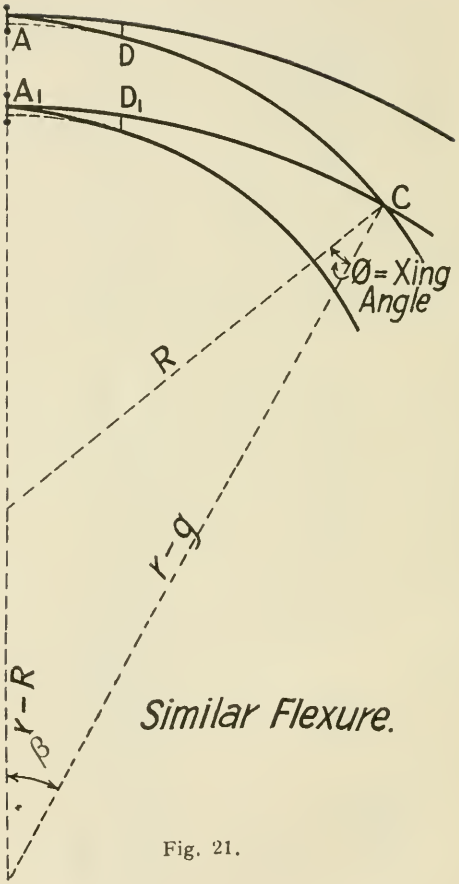


Fig. 21.

For curves of Contrary Flexure (Fig. 22) the switches are left straight and in this case

$$s = \frac{Rr}{(r+R)\,2n^2}$$

Switch lead A D $= 2\,sn^2$.

$$\cos\frac{\alpha}{2} = \sqrt{\frac{S[(S-(r+R-g)]}{Rr}}$$

where $S = \frac{[2\,(r+R)] - g}{2}$

θ = crossing angle $180° - \alpha$

Crossing head $A_1C = r$ arc B

where

$$B = \frac{R \sin \alpha}{r+R-g}$$

Lead $D_1C = A_1C - A\,D$.

The last two formulæ need only be used for fast running junctions where it is intended to string line the curves on the job. The formulæ illustrated by Figs. 16 and 17 are quite near enough for ordinary turnout work.

The length of diamond side A B $= \frac{g}{\sin B}$ (see Fig. 23)

A table calculated on this formula will be found on page 268. For curved diamonds in which both roads are curved to the same radius and in the same direction it will be sufficiently accurate to assume that the length of sides are the same as if both roads were straight.

The distance between two crossings on a crossover road

A B $= \frac{S - g \cos \alpha}{\sin \alpha}$ (see Fig. 24).

In some offices it is the practice when dealing with crossing work where both lines are curved to plot diagrams by means of offsets from a straight line and then scaling the distances and crossing angles, but of course the same accuracy is not obtained as by the calculation methods.

When ordering crossing work it is usual to make a diagram to a scale of about 8 ft. to an inch, giving the radius of curves, angles of crossings and distances between intersections of crossings which are sent to the crossing shops, so that the work may be accurately set out in the shops, while another copy is given to the relaying ganger for use on the ground.

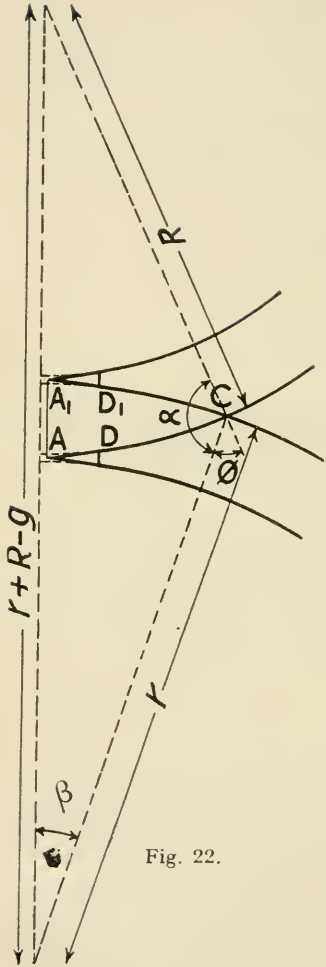


Fig. 22.

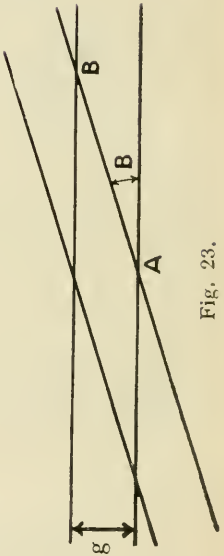


Fig. 23.

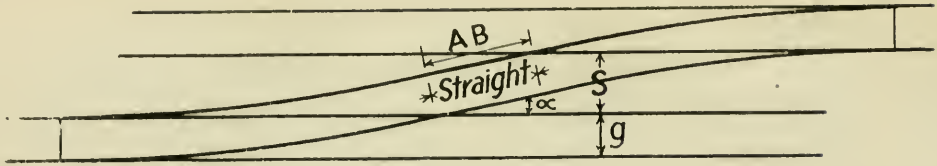


Fig. 24.

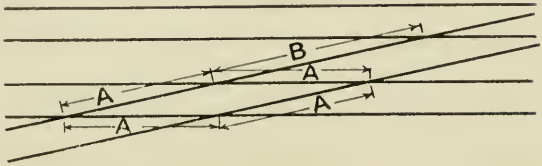


Fig. 25.

TABLE OF DIAMOND DISTANCES FOR 4′ 8½″ GAUGE. (Fig. 25.)

Angle of Diamond 1 in.	Length of Diamond Sides A	Distance B for 6′6″ space between roads.	Distance B for 7′ 6″ space between roads.	Distance B for 8′ 6″ space between roads.	Distance B for 11′ space between roads
2	10′ 0 1/16″	13′ 9¾″	15′ 11¼″	18′ 0¾″	23′ 4½″
2⅛	10′ 6 11/16″	14′ 6 15/16″	16′ 9 13/16″	19′ 0¾″	24′ 8″
2¼	11′ 1⅜″	15′ 4 3/16″	17′ 8½′	20′ 0 13/16″	25′ 11⅝″
2⅜	11′ 8 1/16″	16′ 1 7/16″	18′ 7¼″	21′ 1″	27′ 3⅞″
2½	12′ 2⅞″	16′ 10 13/16″	19′ 6″	22′ 1 3/16″	28′ 7 3/16″
2⅝	12′ 9 11/16″	17′ 8 3/16″	20′ 4 13/16″	23′ 2 9/16″	29′ 11 1/16″
2¾	13′ 4½″	18′ 5 9/16″	21′ 3 11/16″	24′ 1¾″	31′ 3″
2⅞	13′ 11⅝″	19′ 3″	22′ 2 9/16″	25′ 2⅛″	32′ 7″
3	14′ 6¼″	20′ 0½″	23′ 1½″	26′ 2½″	33′ 11″
3⅛	15′ 1⅛′	20′ 10″	24′ 0 7/16″	27′ 2 15/16″	35′ 3 1/16″
3¼	15′ 8″	21′ 7½″	24′ 11 7/16″	28′ 3 5/16″	36′ 7⅛″
3⅜	16′ 2⅞″	22′ 5″	25′ 10 7/16″	29′ 3 13/16″	37′ 11¼″
3½	16′ 9 13/16″	23′ 2 9/16″	26′ 9 7/16″	30′ 4¼″	39′ 3 7/16″
3⅝	17′ 4 11/16″	24′ 0⅛″	27′ 8 7/16″	31′ 4¾″	40′ 7⅝″
3¾	17′ 11⅝″	24′ 9 11/16″	28′ 7½″	32′ 5 3/16″	41′ 11 13/16″
3⅞	18′ 9 9/16″	25′ 7¼″	29′ 6 9/16″	33′ 5 13/16″	43′ 4″
4	19′ 1 9/16″	26′ 4⅞″	30′ 5⅝″	34′ 6⅜″	44′ 8¼″
4¼	20′ 3 1/16″	28′ 0 1/16″	32′ 3 13/16″	36′ 7½″	47′ 4⅜″
4½	21′ 5⅜″	29′ 7 5/16″	34′ 2″	38′ 8 11/16″	50′ 1 5/16″
4¾	22′ 7⅜″	31′ 2 9/16″	36′ 0¼″	40′ 9⅞″	52′ 9 15/16″
5	23′ 9 5/16″	32′ 9⅛″	37′ 10½″	42′ 11 1/16″	55′ 6⅝″
5¼	24′ 11 5/16″	34′ 5 3/16″	39′ 8¾″	45′ 0⅜″	58′ 3¼″
5½	26′ 1 5/16″	36′ 0 9/16″	41′ 7 1/16″	47′ 1⅝″	61′ 0″
5¾	27′ 3 5/16″	37′ 7⅞″	43′ 5 7/16″	49′ 2 15/16″	63′ 8¾″
6	28′ 5⅜″	39′ 3¼″	45′ 3¾″	51′ 4 1/16″	66′ 5½″
6¼	29′ 7⅜″	40′ 10⅝″	47′ 2⅛″	53′ 5 9/16″	69′ 2¼″
6½	30′ 9 7/16″	42′ 6″	49′ 0½″	55′ 6 15/16″	71′ 11 1/16″
6¾	31′ 11 7/16″	44′ 1⅜″	50′ 10 5/16″	57′ 8¼″	74′ 7⅞″
7	33′ 1½″	45′ 8¾″	52′ 9 3/16″	59′ 9⅝″	77′ 4 11/16″
7¼	34′ 3 9/16″	47′ 4 3/16″	54′ 7 9/16″	61′ 11″	80′ 1 9/16″
7½	35′ 5⅝″	48′ 11⅝″	56′ 6″	64′ 0⅜″	82′ 10⅜″
7¾	36′ 7 11/16″	50′ 7″	58′ 4⅜″	66′ 1 13/16″	85′ 7⅛″
8	37′ 9¾″	52′ 2 7/16″	60′ 2 13/16″	68′ 3 3/16″	88′ 4⅛″
9	42′ 6 1/16″	58′ 8⅛″	—	—	—
10	47′ 2⅜″	65′ 2″	—	—	—
12	58′ 7⅛″	78′ 1 9/16″	—	—	—

TABLE OF SWITCH LEADS AND DISTANCES AND TRIGONOMETRICAL FUNCTIONS FOR LEADS TANGENTIAL TO MAIN LINE (see Fig. 15). GAUGE 4′ 8½″.

Crossing No.	Angle of Crossing.	Radius of Lead Rail.	Switch Lead.	Crossing Lead.	Lead.	Log R.	Natural Sine.	Natural Cosine.	Logarithmic Sine.	Logarithmic Cosine.	Logarithmic Cotangent.	Logarithmic Versed Sine.	Crossing No.
		ft.	ft.	ft.									
4	14° 15′ 00″	150·67	10·51	37·67	27′ 2″	2·17801	·24615	·96923	9·39120	9·98642	10·59522	8·48811	4
4½	12° 40′ 59″	190·69	11·96	42·37	30′ 5″	2·28032	·21951	·97561	9·34145	9·98927	10·64782	8·38721	4½
5	11° 25′ 16″	235·42	13·29	47·08	33′ 9½″	2·37183	·19802	·98020	9·29670	9·99131	10·69461	8·29670	5
5½	10° 23′ 20″	284·85	14·61	51·79	37′ 2″	2·45462	·18033	·98360	9·25606	9·99282	10·73675	8·21467	5½
6	9° 31′ 38″	339·00	15·94	56·50	40′ 6¾″	2·53020	·16552	·98621	9·21884	9·99397	10·77513	8·13966	6
6½	8° 47′ 51″	397·85	17·27	61·21	43′ 11¼″	2·59972	·15294	·98823	9·18453	9·99486	10·81033	8·07058	6½
7	8° 10′ 16″	461·42	18·60	65·92	47′ 4″	2·66409	14213	98985	9·15268	9 99557	10·84288	8·00655	7
7½	7° 37′ 41″	529·69	19·93	70·62	50′ 8¼″	2·72402	·13274	·99115	9·12301	9·99614	10·87313	7·94691	7½
8	7° 09′ 10″	602·67	21·26	75·33	54′ 1″	2·78007	·12452	·99222	9·09522	9·99660	10·90138	7·89110	8
8½	6° 43′ 59″	680·36	22·59	80·04	57′ 5½″	2·83273	·11724	·99310	9·06909	9·99699	10·92790	7·83864	8½
9	6° 21′ 35″	762·75	23·92	84·75	60′ 10″	2·88238	·11077	·99385	9·04442	9·99732	10·95289	7·78915	9
9½	6° 01′ 32″	849·85	25·25	89·46	64′ 2½″	2·92934	·10497	·99448	9·02107	9·99759	10·97652	7·74232	9½
10	5° 43′ 29″	941·67	26·58	94·17	67′ 7″	2·97389	·09975	·99501	8·99891	9·99783	10·99892	7·69788	10
10½	5° 27′ 09″	1038·19	27·90	98·87	70′ 11¼″	3·01627	09502	99548	8 97781	9·99803	11·02021	7·65560	10½
11	5° 12′ 18″	1139·42	29·23	103·58	74′ 4¼″	3·05668	·09072	·99588	8·95770	9·99820	11·04050	7·61528	11
11½	4° 58′ 45″	1245·36	30·56	108·29	77′ 9″	3·09529	·08679	·99623	8·93848	9·99836	11·05987	7·57676	11½
12	4° 46′ 19″	1356·00	31·89	113·00	81′ 1¼″	3·13226	·08319	·99653	8·92007	9·99849	11·07842	7·53986	12

TABLE FOR FINDING THE RADIUS OF A CURVE
by measuring the offset from a chord of one chain in length
one chain = 66 feet.

Offset in Inches.	Radius in Chains.	Offset in Inches.	Radius in Chains.	Offset in Inches.	Radius in Chains.
19 13/16	5	5 7/8	17	1 7/16	70
18 1/16	5 1/2	5 1/2	18	1 9/16	75
16 9/16	6	5 1/4	19	1 3/16	80
15 1/4	6 1/2	4 15/16	20	1 1/16	90
14 3/16	7	4 1/2	22 1/2	1	100
13 1/4	7 1/2	3 15/16	25	7/8	110
12 1/16	8	3 5/8	27 1/2	13/16	120
11 11/16	8 1/2	3 5/16	30	3/4	130
11	9	3 1/16	32 1/2	11/16	140
10 7/16	9 1/2	2 13/16	35	2 1/32	150
9 7/8	10	2 11/16	37 1/2	5/8	160
9	11	2 1/2	40	1 7/32	180
8 1/4	12	2 3/16	45	1/2	200
7 5/8	13	2	50	7/16	220
7 1/16	14	1 13/16	55	1 3/32	240
6 5/8	15	1 11/16	60	3/8	260
6 3/16	16	1 9/16	65	1 1/32	280

Difference in length of Inner and Outer Rail in Curves (Frank Reeves).

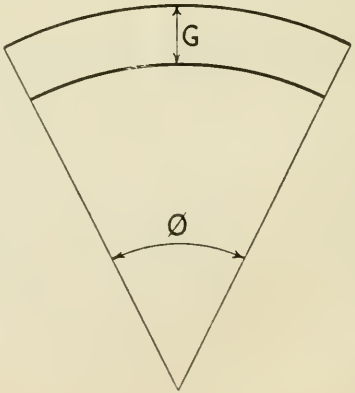


Fig. 26.

DIFFERENCE IN LENGTH OF INNER AND OUTER RAIL IN CURVES (Frank Reeves).

Fig. 26.

φ = Central angle of curve in degrees.
G = Gauge of railway (in any unit).
D = Difference in length (in the same unit).

$$D = \frac{\varphi G \pi}{180} = \cdot 01745 \varphi G.$$

THE IMPROVEMENT OF EXISTING CURVES

Most of the railways in Great Britain have been constructed with circular curves.

When the radius is large, and the cant eased off gently, the circular curve seems suitable and is easily set out, but with high speeds in the interests of safety and comfort some form of transition curve is desirable.

Much of this improvement work is going on just now, and probably one of the best processes to be adopted is that in use on the London & South Western Railway, devised by one of their engineers, Mr. W. H. Shortt, and described by him in Vol. clxxvi. of the Minutes of the Institution of Civil Engineers.

The office and field work incidental to any piece of such improvement are performed in six stages, *viz.*:—

(1) Surveying the existing curves and tangents, noting all fixed points which might be likely to foul the structure gauge.
(2) Plotting the survey to a distorted scale so that small variations are readily detected.
(3) Drawing of improved curves on tracing paper and fitting them over the survey, to ascertain whether fixed points are fouled; and then drawing them on the survey.
(4) Setting out the new curve on the ground.
(5) Checking the setting out.
(6) Pulling the track into the new position.

At stage (2) convenient scales for the plotting are found to be—

Lengths along the base line .. 40 ft. to an inch
Lengths at right angles to the base line 4 ft. to an inch
All radii .. .. 4 0 ft. to an inch

Since "If a given circular arc be plotted with the radius struck to a scale of a-b feet to the inch and the length of the arc marked off to a scale of a foot to the inch, then a scale of $\frac{a}{b}$ feet to the inch must be used to scale off the true distance of any point from the arc, provided such distance be small compared with the radius of the arc."

Much has been written on the question of the correct form of curve for transition purposes, but that very generally adopted is that portion of the cubic parabola between the origin and the point of maximum curvature.

From the equation to this curve the offsets are calculated in the manner described on page 235.

Suitable alignment having been worked up in the office, offsets from the existing curve are scaled from the survey. These are pegged out on the site, and checked there before the road is pulled to the new position.

It is claimed that the survey of a simple curve may be made by one engineering assistant and two chainmen, the results plotted, and the improvement decided upon in the office in one day, pegged out and checked on the second, and the road slued to the new position on the third.

ELECTRIC EQUIPMENT OF RAILWAY TRACKS.

In these notes it is not intended to go into the question of electric track equipment from the electrician's point of view, but merely to describe those portions which are usually in the maintenance of the Permanent Way Dept.

The system most generally adopted in this country and America is that known as the Continuous Current Third Rail System, in which the electric current is supplied to an insulated rail conductor, at about rail level, at a pressure of 600 volts, the return current being taken either on the running rails or on a fourth rail provided for the purpose.

On the Central London Line, for example, the supply or positive rail is in the centre of the four-foot, and the return current is taken on the running rails, but on the London Electric Co.'s Tubes, the Metropolitan, the District, the North-Eastern and other systems the positive rail is outside the track and an insulated fourth or negative rail is provided in the centre of the track for the return current, the position of these rails being as indicated in Fig. 1.

The insulated negative rail is now compulsory for railways in the London area, to prevent leakage of current from interfering with the delicate apparatus at Greenwich Observatory.

The conductor rails are carried on porcelain insulators and are connected by cast-iron joint plates and copper bonds, and are fixed at such heights that the collector shoes clear the other rails. On the London systems the positive rail is placed 3″ and negative rail $1\frac{1}{2}$″ above the running rails.

There is some difference in practice in regard to the section of conductor rails and type of insulators used. On the Metropolitan, District and the North-Eastern Lines, the T or flange-section rail is used (see Fig. 1),

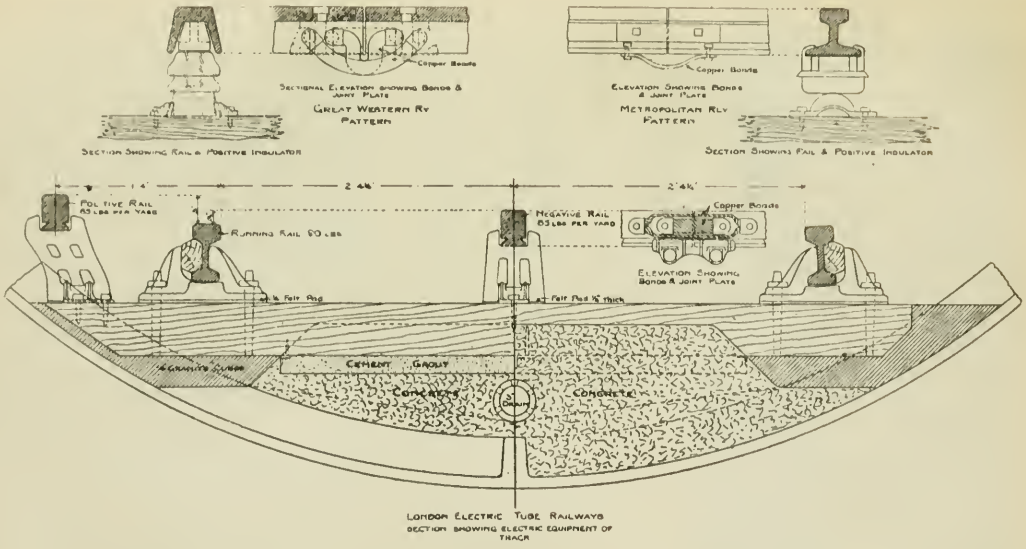

Copper Bonds
Sectional Elevation showing Bonds & Joint Plate
Great Western Ry Pattern
Section showing Rail & Positive Insulator
Copper Bonds
Elevation Showing Bonds & Joint Plate
Metropolitan Rly Pattern
Section Showing Rail & Positive Insulator
1' 2 4½" 2' 4½"
Positive Rail 85 lbs per yard
Running Rail 80 lbs
Negative Rail 85 lbs per yard
Copper Bonds
Elevation Showing Bonds & Joint Plate
½ Fair Pad
½ Fair Pad ½" thick
6 Granite Sleeper
Cement Grout
Concrete
Concrete
Grout
London Electric Tube Railways
Section showing electric equipment of track

Fig. 1.

and as this form is top-heavy, the rails have to be firmly secured to the insulators by clips, thus allowing for very little elasticity in the running rails, but on the London Electric Tube Railways and the Great Western "City" Lines, the insulators are free to move up and down with the sleepers, the object being to prevent any undue strain upon the porcelain portion.

In the Tube Railway pattern the rails are of a solid rectangular section resting directly on the porcelain, see Fig. 1, which also shows the arrangements of the joint plates and copper bonds.

In the Great Western pattern a channel section rail is used, and the insulator has a cast-iron head, which is fixed in the porcelain by means of Portland cement. The patterns of insulator, rail, joint plate and bonds are shown in Fig. 2.

It is usual to have four bonds to each joint, one long and one short on each side of the rail, and these are made either of twisted copper wire or of flat laminations with a plug at each end.

Great care is taken in bonding rails to obtain perfect contact.

The holes in the rails are first reamered bright and the plug is then inserted and pressed with a hydraulic machine, giving a pressure of about 30 tons until the hole is completely closed.

The connections with the feeder cables are brought up through special insulators and connected in a similar way.

Guard boards are attached to the positive rails at places where porters and others are likely to walk about, to prevent them from getting shocks.

Where crossing work occurs it is necessary to break the rails as shown in Fig. 2. Where these breaks occur ramps are made at the ends of the rails and cables, known as "jumper" cables, connect the ends of the rails. These cables (shown in dotted lines) are taken down through insulators and then underground in the same way as the feeders. The ramps for main lines are made of steel and have an angle of about 1 in 50 for facing direction and 1 in 8 for trailing direction. For siding work cast-iron ramps are used, having an angle of about 1 in 8. Opposite to switches, inclines in the positive rail are made, and the depression is sufficient to clear the collector shoe to prevent it travelling across the rail, and sparking at the sides. Wooden bridging pieces are used over the locking mechanisms at facing points. Care must be taken to prevent the gaps in the positive rail at crossing work being longer than the shortest train, so that the collector shoe at one end of the train will be always in contact.

The conductor rails are divided up into sections, which may be disconnected as required when a fault occurs, or repairs are necessary.

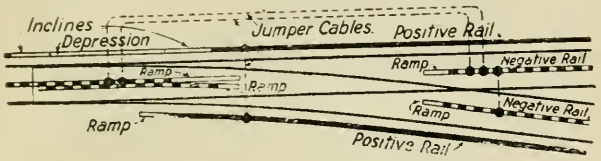

Inclines
Depression
Jumper Cables.
Positive Rail.
Ramp
Ramp
Negative Rail
Ramp
Ramp
Negative Rail
Ramp
Positive Rail

Fig. 2.

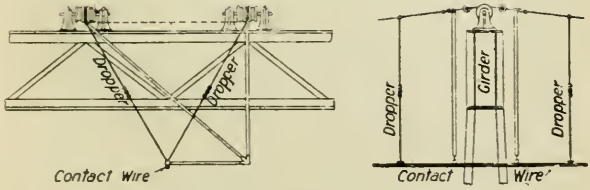

Dropper
Dropper
Contact Wire
Dropper
Girder
Dropper
Contact Wire

Fig. 3.

Great care should be taken by permanent way men to prevent anything from touching the conductor rails, and in the event of fire to extinguish it with dry sand only. Insulated tools only should be used.

The steel for conductor rails is very soft, and in order to increase its conductivity the percentage of pure iron is kept as high as possible and the percentage of carbon and manganese very low. The conductivity should be about 12½% of the standard for pure copper, and the tensile strength 22 to 28 tons per sq. in.

The porcelain for insulators should be of a very dense fine grain, and covered with a glaze which is impermeable to water.

The insulators for a 600-volt circuit are tested to 2,000 volts alternating current for five minutes after twenty-four hours' immersion in water.

OVERHEAD EQUIPMENT.

This type of equipment has recently been introduced on the London, Brighton and South Coast Railway. In this case a 6,000 volt single-phase alternating current has been adopted with overhead wires suspended from light lattice girders on the double catenary principle.

This type of construction is designed to keep the contact wire as near as possible parallel to the running rails and in as good a line as possible in order to prevent the collector bow from "whipping."

It consists of two twisted galvanized steel wire catenary cables, which hang in their natural curve and from which are suspended at intervals of 10 ft. the copper contact wire, by means of dropper wires linked in the middle. With a view to preventing swaying the catenary cables are also connected by wires, which are always of such length as to form with the dropper wires an equilateral triangle.

The contact wire is of circular section ½" in diameter, into which phosphor bronze clips are clamped to connect the dropper wires.

Fig. 3 shows the method of suspension.

The insulators are of the corrugated spool type, having a steel tube inside to prevent undue strain on the porcelain at the bearing pin.

* * * * * *

The many problems connected with Signalling and Permanent Way Engineering that are constantly arising are dealt with from time to time in the proceedings of the Institution of Railway Signal Engineers and Permanent Way Institution respectively.

METRIC MEASURES WITH BRITISH EQUIVALENTS.

Square Metres in Square Feet.

S. M.	Sq. Ft.	S. M.	Sq. Ft.	S. M.	Sq. Ft.	S. M.	Sq. Ft.
1	10.764	26	279.872	51	548.979	76	818.087
2	21.529	27	290.636	52	559.744	77	828.851
3	32.293	28	301.40	53	570.508	78	839.615
4	43.057	29	312.165	54	581.272	79	850.38
5	53.821	30	322.929	55	592.036	80	861.144
6	64.586	31	333.693	56	602.801	81	871.908
7	75.35	32	344.458	57	613.565	82	882.673
8	86.114	33	355.222	58	624.329	83	893.437
9	96.879	34	365.986	59	635.094	84	904.201
10	107.643	35	376.75	60	645.858	85	914.965
11	118.407	36	387.515	61	656.622	86	925.73
12	129.172	37	398.279	62	667.387	87	936.494
13	139.936	38	409.043	63	678.151	88	947.258
14	150.7	39	419.808	64	688.915	89	958.023
15	161.464	40	430.572	65	699.679	90	968.787
16	172.229	41	441.336	66	710.444	91	979.551
17	182.993	42	452.101	67	721.208	92	990.316
18	193.757	43	462.865	68	731.972	93	1001.08
19	204.522	44	473.629	69	742.737	94	1011.844
20	215.286	45	484.393	70	753.501	95	1022.608
21	226.05	46	495.158	71	764.265	96	1033.373
22	236.815	47	505.922	72	775.03	97	1044.137
23	247.579	48	516.686	73	785.794	98	1054.901
24	258.343	49	527.451	74	796.558	99	1065.666
25	269.107	50	538.215	75	807.322	100	1076.43

BRITISH MEASURES WITH METRIC EQUIVALENTS.

Square Feet in Square Metres.

Sq. Feet.	Sq. Metres.	Sq. Feet.	Sq. Metres.	Sq. Feet.	Sq. Metres.	Sq. Feet.	Sq. Metres.
1	.0929	26	2.4154	51	4.7379	76	7.0604
2	.1858	27	2.5083	52	4.8308	77	7.1533
3	.2787	28	2.6012	53	4.9237	78	7.2462
4	.3716	29	2.6941	54	5.0166	79	7.3391
5	.4645	30	2.787	55	5.1095	80	7.432
6	.5574	31	2.8799	56	5.2024	81	7.5249
7	.6503	32	2.9728	57	5.2953	82	7.6178
8	.7432	33	3.0657	58	5.3882	83	7.7107
9	.8361	34	3.1586	59	5.4811	84	7.8036
10	.929	35	3.2515	60	5.574	85	7.8965
11	1.0219	36	3.3444	61	5.6669	86	7.9894
12	1.1148	37	3.4373	62	5.7598	87	8.0823
13	1.2077	38	3.5302	63	5.8527	88	8.1752
14	1.3006	39	3.6231	64	5.9456	89	8.2681
15	1.3935	40	3.716	65	6.0385	90	8.361
16	1.4864	41	3.8089	66	6.1314	91	8.4539
17	1.5793	42	3.9018	67	6.2243	92	8.5468
18	1.6722	43	3.9947	68	6.3172	93	8.6397
19	1.7651	44	4.0876	69	6.4101	94	8.7326
20	1.858	45	4.1805	70	6.503	95	8.8255
21	1.9509	46	4.2734	71	6.5959	96	8.9184
22	2.0438	47	4.3663	72	6.6888	97	9.0113
23	2.1367	48	4.4592	73	6.7817	98	9.1042
24	2.2296	49	4.5521	74	6.8746	99	9.1971
25	2.3225	50	4.645	75	6.9675	100	9.29

METRIC MEASURES WITH BRITISH EQUIVALENTS.

Metres in Feet.

Mtrs.	Feet.	Mtrs.	Feet.	Mtrs	Feet.	Mtrs	Feet.
1	3.2809	26	85.3034	51	167.3258	76	249.3483
2	6.5618	27	88.5843	52	170.6067	77	252.6292
3	9.8427	28	91.8652	53	173.8876	78	255.9101
4	13.1236	29	95.1461	54	177.1685	79	259.191
5	16.4045	30	98.427	55	180.4494	80	262.4719
6	19.6854	31	101.7079	56	183.7303	81	265.7528
7	22.9663	32	104.9888	57	187.0112	82	269.0337
8	26.2472	33	108.2697	58	190.2921	83	272.3146
9	29.5281	34	111.5506	59	193.573	84	275.5955
10	32.809	35	114.8315	60	196.8539	85	278.8764
11	36.0899	36	118.1124	61	200.1348	86	282.1573
12	39.3708	37	121.3933	62	203.4157	87	285.4382
13	42.6517	38	124.6742	63	206.6966	88	288.7191
14	45.9326	39	127.9551	64	209.9775	89	292.
15	49.2135	40	131.236	65	213.2584	90	295.2809
16	52.4944	41	134.5169	66	216.5393	91	298.5618
17	55.7753	42	137.7978	67	219.8202	92	301.8427
18	59.0562	43	141.0787	68	223.1011	93	305.1236
19	62.3371	44	144.3596	69	226.382	94	308.4045
20	65.618	45	147.6405	70	229.6629	95	311.6854
21	68.8989	46	150.9214	71	232.9438	96	314.9663
22	72.1798	47	154.2023	72	236.2247	97	318.2472
23	75.4607	48	157.4832	73	239.5056	98	321.5281
24	78.7416	49	160.7641	74	242.7865	99	324.809
25	82.0225	50	164.045	75	246.0674	100	328.0899

BRITISH MEASURES WITH METRIC EQUIVALENTS.

Feet in Metres.

Feet.	Metres.	Feet	Metres.	Feet.	Metres.	Feet.	Metres.
1	.3048	26	7.9246	51	15.5445	76	23.1643
2	.6096	27	8.2294	52	15.8493	77	23.4691
3	.9144	28	8.5342	53	16.1541	78	23.7739
4	1.2192	29	8.8390	54	16.4589	79	24.0797
5	1.524	30	9.1438	55	16.7637	80	24.3835
6	1.8288	31	9 4486	56	17.0685	81	24.6883
7	2.1335	32	9.7534	57	17.3733	82	24.9931
8	2.4383	33	10.0582	58	17.6780	83	25.2979
9	2.7431	34	10.3630	59	17.9828	84	25.6027
10	3.0479	35	10.6678	60	18.2876	85	25.9075
11	3.3527	36	10.9726	61	18.5924	86	26.2123
12	3.6575	37	11.2774	62	18.8972	87	26.5171
13	3.9623	38	11.5822	63	19.2020	88	26.8219
14	4.2671	39	11.8870	64	19.5068	89	27.1267
15	4.5719	40	12.1918	65	19.8116	90	27.4315
16	4.8767	41	12.4966	66	20.1164	91	27.7363
17	5.1815	42	12.8013	67	20.4212	92	28.0410
18	5.4863	43	13.1061	68	20.7260	93	28.3458
19	5.7911	44	13.4109	69	21.0308	94	28.6506
20	6.0959	45	13.7157	70	21.3356	95	28.9554
21	6.4007	46	14.0205	71	21.6404	96	29.2602
22	6.7055	47	14.3253	72	21.9452	97	29.5650
23	7.0103	48	14.6301	73	22.2500	98	29.8108
24	7.3151	49	14.9349	74	22.5548	99	30.1746
25	7.6198	50	15.2397	75	22.8595	100	30.4794

METRIC MEASURES WITH BRITISH EQUIVALENTS.

Kilometres in Miles.

Km.	Miles.	Km.	Miles.	Km.	Miles.	Km.	Miles.
1	0.621	26	16.156	51	31.690	76	47.225
2	1.243	27	16.777	52	32.312	77	47.846
3	1.864	28	17.399	53	32.933	78	48.468
4	2.485	29	18.02	54	33.554	79	49.089
5	3.107	30	18.641	55	34.176	80	49.710
6	3.728	31	19.263	56	34.797	81	50.332
7	4.350	32	19.884	57	35.419	82	50.953
8	4.971	33	20.505	58	36.040	83	51.574
9	5.592	34	21.127	59	36.661	84	52.196
10	6.214	35	21.748	60	37.283	85	52.817
11	6.835	36	22.370	61	37.904	86	53.439
12	7.457	37	22.991	62	38.525	87	54.06
13	8.078	38	23.612	63	39.147	88	54.681
14	8.699	39	24.234	64	39.768	89	55.303
15	9.321	40	24.855	65	40.390	90	55.924
16	9.942	41	25.477	66	41.011	91	56.545
17	10.563	42	26.098	67	41.632	92	57.167
18	11.185	43	26.719	68	42.254	93	57.788
19	11.806	44	27.341	69	42.875	94	58.410
20	12.428	45	27.962	70	43.497	95	59.031
21	13.049	46	28.583	71	44.118	96	59.652
22	13.670	47	29.205	72	44.739	97	60.274
23	14.292	48	29.826	73	45.361	98	60.895
24	14.913	49	30.448	74	45.982	99	61.517
25	15.534	50	31.069	75	46.603	100	62.138

BRITISH MEASURES WITH METRIC EQUIVALENTS.

Miles in Kilometres.

Miles	Kilo-metres.	Miles	Kilo-metres.	Miles	Kilo-metres.	Miles	Kilo-metres.
1	1.609321	26	41.842346	51	82.075371	76	122.308396
2	3.218642	27	43.451667	52	83.684692	77	123.917717
3	4.827963	28	45.060988	53	85.294013	78	125.527038
4	6.437284	29	46.670309	54	86.903334	79	127.136359
5	8.046605	30	48.27963	55	88.512655	80	128.74568
6	9.655926	31	49.888951	56	90.121976	81	130.355001
7	11.265247	32	51.498272	57	91.731297	82	131.964322
8	12.874568	33	53.107593	58	93.340618	83	133.573643
9	14.483889	34	54.716914	59	94.949939	84	135.182964
10	16.09321	35	56.326235	60	96.55926	85	136.792285
11	17.702531	36	57.935556	61	98.168581	86	138.401606
12	19.311852	37	59.544877	62	99.777902	87	140.010927
13	20.921173	38	61.154198	63	101.387223	88	141.620248
14	22.530494	39	62.763519	64	102.996544	89	143.229569
15	24.139815	40	64.37284	65	104.605865	90	144.83889
16	25.749136	41	65.982161	66	106.215186	91	146.448211
17	27.358457	42	67.591482	67	107.824507	92	148.057532
18	28.967778	43	69.200803	68	109.433828	93	149.666853
19	30.577099	44	70.810124	69	111.043149	94	151.276174
20	32.18642	45	72.419445	70	112.65247	95	152.885495
21	33.795741	46	74.028766	71	114.261791	96	154.494816
22	35.405062	47	75.638087	72	115.871112	97	156.104137
23	37.014383	48	77.247408	73	117.480433	98	157.713458
24	38.623704	49	78.856729	74	119.089754	99	159.322779
25	40.233025	50	80.46605	75	120.699075	100	160.9321

METRIC MEASURES WITH BRITISH EQUIVALENTS

Kilogrammes in Pounds

Kg.	Pounds.	Kg.	Pounds	Kg.	Pounds.	Kg.	Pounds.
1	2.205	26	57.320	51	112.435	76	167.550
2	4.409	27	59.524	52	114.639	77	169.754
3	6.614	28	61.729	53	116.844	78	171.959
4	8.818	29	63.933	54	119.048	79	174.163
5	11.023	30	66.138	55	121.253	80	176.368
6	13.228	31	68.343	56	123.458	81	178.573
7	15.432	32	70.547	57	125.662	82	180.777
8	17.637	33	72.752	58	127.867	83	182.982
9	19.841	34	74.956	59	130.071	84	185.186
10	22.046	35	77.161	60	132.276	85	187.391
11	24.251	36	79.366	61	134.481	86	189.596
12	26.455	37	81.570	62	136.685	87	191.800
13	28.660	38	83.775	63	138.890	88	194.005
14	30.864	39	85.979	64	141.094	89	196.209
15	33.069	40	88.184	65	143.299	90	198.414
16	35.274	41	90.389	66	145.504	91	200.619
17	37.478	42	92.593	67	147.708	92	202.823
18	39.683	43	94.798	68	149.913	93	205.028
19	41.887	44	97.002	69	152.117	94	207.232
20	44.092	45	99.207	70	154.322	95	209.437
21	46.297	46	101.412	71	156.527	96	211.642
22	48.501	47	103.616	72	158.731	97	213.846
23	50.706	48	105.821	73	160.936	98	216.051
24	52.910	49	108.025	74	163.140	99	218.255
25	55.115	50	110.23	75	165.345	100	220.462

BRITISH MEASURES WITH METRIC EQUIVALENTS.

Pounds in Kilogrammes.

Lbs.	Kilogrammes.	Lbs.	Kilogrammes.	Lbs.	Kilogrammes.	Lbs.	Kilogrammes.
1	.453593	26	11.793418	51	23.133243	76	34.473068
2	.907186	27	12.247011	52	23.586836	77	34.926661
3	1.360779	28	12.700604	53	24.040429	78	35.380254
4	1.814372	29	13.154197	54	24.494022	79	35.833847
5	2.267965	30	13.60779	55	24.947615	80	36.28744
6	2.721558	31	14.061383	56	25.481208	81	36.741033
7	3.175151	32	14.514976	57	25.854801	82	37.194626
8	3.628744	33	14.968569	58	26.308394	83	37.648219
9	4.082337	34	15.422162	59	26.761987	84	38.101812
10	4.53593	35	15.875755	60	27.21558	85	38.555405
11	4.989523	36	16.329348	61	27.669173	86	39.008998
12	5.443116	37	16.782941	62	28.122766	87	39.462591
13	5.896709	38	17.236534	63	28.576359	88	39.916184
14	6.350302	39	17.690127	64	29.029952	89	40.639771
15	6.803895	40	18.14372	65	29.483545	90	40.82337
16	7.257488	41	18.597313	66	29.937138	91	41.276963
17	7.711081	42	19.050906	67	30.390731	92	41.730556
18	8.164674	43	19.504499	68	30.844324	93	42.184149
19	8.618267	44	19.958092	69	31.297917	94	42.637742
20	9.07186	45	20.411685	70	31.75151	95	43.091335
21	9.525453	46	20.865278	71	32.205103	96	43.544928
22	9.979046	47	21.318871	72	32.658696	97	43.998521
23	10.432639	48	21.772464	73	33.112289	98	44.452114
24	10.886232	49	22.226057	74	33.565882	99	44.905707
25	11.339825	50	22.67965	75	34.019475	100	45.3593

METRIC MEASURES WITH BRITISH EQUIVALENTS.

Litres in Imperial Gallons.

Litres.	Gallons.	Litres.	Gallons.	Litres.	Gallons.	Litres.	Gallons.
1	.22	26	5.72	51	11.22	76	16.73
2	.44	27	5.94	52	11.44	77	16.95
3	.66	28	6.16	53	11.67	78	17.17
4	.88	29	6.38	54	11.89	79	17.39
5	1.10	30	6.60	55	12.11	80	17.61
6	1.32	31	6.82	56	12.33	81	17.85
7	1.54	32	7.04	57	12.55	82	18.05
8	1.76	33	7.26	58	12.77	83	18.27
9	1.98	34	7.48	59	12.99	84	18.49
10	2.20	35	7.70	60	13.21	85	18.71
11	2.42	36	7.92	61	13.43	86	18.93
12	2.64	37	8.14	62	13.65	87	19.15
13	2.86	38	8.36	63	13.87	88	19.37
14	3.08	39	8.58	64	14.09	89	19.59
15	3.30	40	8.80	65	14.31	90	19.81
16	3.52	41	9.02	66	14.53	91	20.03
17	3.74	42	9.24	67	14.75	92	20.25
18	3.96	43	9.46	68	14.97	93	20.47
19	4.18	44	9.68	69	15.19	94	20.69
20	4.40	45	9.90	70	15.41	95	20.91
21	4.62	46	10.12	71	15.63	96	21.13
22	4.84	47	10.34	72	15.85	97	21.35
23	5.06	48	10.56	73	16.07	98	21.57
24	5.28	49	10.78	74	16.29	99	21.79
25	5.50	50	11.00	75	16.51	100	22.01

BRITISH MEASURES WITH METRIC EQUIVALENTS.

Imperial Gallons in Litres.

Gal.	Litres.	Gal.	Litres.	Gal.	Litres.	Gal.	Litres.
1	4.543	26	118.130	51	231.717	76	345.304
2	9.087	27	122.674	52	236.260	77	349.847
3	13.630	28	127.217	53	240.804	78	354.391
4	18.174	29	131.761	54	245.347	79	358.934
5	22.717	30	136.304	55	249.891	80	363.478
6	27.261	31	140.848	56	254.434	81	368.021
7	31.804	32	145.391	57	258.978	82	372.565
8	36.348	33	149.935	58	263.521	83	377.108
9	40.891	34	154.478	59	268.065	84	381.651
10	45.435	35	159.021	60	272.608	85	386.195
11	49.978	36	163.565	61	277.152	86	390.738
12	54.522	37	168.108	62	281.695	87	395.282
13	59.065	38	172.652	63	286.239	88	399.825
14	63.609	39	177.195	64	290.782	89	404.369
15	68.152	40	181.739	65	295.326	90	408.912
16	72.696	41	186.282	66	299.869	91	413.456
17	77.239	42	190.826	67	304.412	92	417.999
18	81.782	43	195.369	68	308.956	93	422.543
19	86.326	44	199.913	69	313.499	94	427.086
20	90.869	45	204.456	70	318.043	95	431.630
21	95.413	46	209.000	71	322.586	96	436.173
22	99.956	47	213.543	72	327.130	97	440.717
23	104.500	48	218.087	73	331.673	98	445.260
24	109.043	49	222.630	74	336.217	99	449.804
25	113.587	50	227.173	75	340.760	100	454.347

METRIC MEASURES WITH BRITISH EQUIVALENTS.

Kilogrammes per Square Centimetre in Pounds per Square Inch.

Kgs. per Sq. Centim.	Lbs. per Sq. In.	Kgs. per Sq. Centim.	Lbs. per Sq. In.	Kgs. per Sq. Centim.	Lbs. per Sq. In.	Kgs. per Sq. Centim.	Lbs. per Sq. In.
1.	14.223	3.6	51.203	6.2	88.183	8.8	125.162
1.1	15.645	3.7	52.625	6·3	89.605	8.9	126.585
1.2	17.068	3.8	54.047	6 4	91.027	9.	128.007
1.3	18.490	3.9	55.470	6.5	92.450	9.1	129.429
1.4	19.912	4.	56.892	6.6	93.872	9.2	130.852
1.5	21.335	4.1	58.314	6.7	95.294	9.3	132.274
1.6	22.757	4.2	59.737	6.8	96.716	9.4	133.696
1.7	24.179	4.3	61.159	6.9	98.139	9.5	135.119
1.8	25.601	4.4	62.581	7.	99.561	9.6	136.541
1.9	27.024	4.5	64.004	7.1	100.983	9.7	137.963
2.	28.446	4.6	65.426	7.2	102.406	9.8	139.385
2.1	29.868	4.7	67.848	7.3	103.828	9.9	140.808
2.2	31 291	4.8	68.270	7.4	105.250	10.	142.230
2.3	32.713	4 9	69.693	7.5	106.673	10.1	143.652
2.4	34.135	5.	71.115	7 6	108.095	10.2	145.074
2.5	35.558	5 1	72.537	7.7	109.517	10.3	146.497
2.6	36.980	5.2	73.960	7 8	110.939	10.4	147.919
2.7	38.402	5.3	75.382	7.9	112.362	10.5	149.341
2.8	39.824	5.4	76.804	8.	113.784	10.6	150.764
2.9	41.247	5.5	78.227	8.1	115.206	10.7	152.186
3.	42.669	5.6	79.649	8.2	116.629	10.8	153.608
3.1	44.091	5.7	81.071	8.3	118.051	10.9	155.030
3.2	45.514	5.8	82.493	8.4	119.473	11.	156.453
3.3	46.936	5.9	83.916	8.5	120.896	11.1	157.875
3.4	48.358	6.	85.338	8 6	122.318	11.2	159.297
3.5	49.781	6.1	86.760	8.7	123.740	11.3	160.720

BRITISH MEASURES WITH METRIC EQUIVALENTS.

Pounds Per Square Inch in Kilogrammes Per Square Centimetre.

Lbs. per Sq. In.	Kgs. per Square Centi-metre.	Lbs. per Sq. In.	Kgs. per Square Centi-metre.	Lbs. per Sq. In.	Kgs. per Square Centi-metre.	Lbs. per Sq. In.	Kgs. per Square Centi-metre.
1	·0703	26	1·828	51	3·5857	76	5·3434
2	.1406	27	1.8983	52	3.656	77	5.4138
3	.2109	28	1.9686	53	3.7263	78	5.4841
4	.2812	29	2.0389	54	3.7966	79	5.5544
5	·3515	30	2.1092	55	3.8669	80	5.6247
6	.4218	31	2·1795	56	3.9373	81	5.695
7	.4921	32	2.2498	57	4.0076	82	5.7653
8	.5624	33	2.3202	58	4.0779	83	5.8356
9	.6327	34	2.3905	59	4.1482	84	5.9059
10	.70309	35	2.4608	60	4.2185	85	5.9762
11	.7734	36	2.5311	61	4.2888	86	6.0465
12	.8437	37	2.6014	62	4.3591	87	6.1168
13	.9140	38	2.6717	63	4.4294	88	6.1872
14	.9843	39	2.7420	64	4.4997	89	6.2575
15	1.0546	40	2.8123	65	4.5700	90	6.3278
16	1.1249	41	2.8826	66	4.6404	91	6.3981
17	1.1952	42	2.9529	67	4.7107	92	6.4684
18	1.2655	43	3.0232	68	4.781	93	6.5387
19	1.3358	44	3.0936	69	4.8513	94	6.609
20	1.4062	45	3.1639	70	4.9216	95	6.6793
21	1.4765	45	3.2342	71	4.9919	96	6.7496
22	1.5468	47	3.3045	72	5.0622	97	6.8199
23	1.6171	48	3.3748	73	5.1325	98	6.8902
24	1.6874	49	3.4451	74	5.2028	99	6.9606
25	1.7577	50	3.5154	75	5.2731	100	7.0309

RADII OF BOXWOOD CURVES.

Radius in Chains.	$\frac{1}{2500}$	$\frac{1}{500}$	Feet to an Inch.			
			50	40	20	33
1	·3	1·6	1·3	1·6	3·3	2
1½	·4	2·4	2·0	2·5	4·9	3
2	·6	3·2	2·6	3 3	6·6	4
2½	·8	4·0	3·3	4·1	8·2	5
3	·9	4·8	4·0	4·9	9·9	6
3½	1·1	5·5	4·6	5·8	11·5	7
4	1·3	6·3	5·3	6·6	13·2	8
4½	1·4	7·1	5·9	7·4	14·8	9
5	1·6	7·9	6·6	8·2	16·5	10
5½	1·7	8·7	7·3	9·0	18·1	11
6	1·9	9·5	7·9	9·9	19·8	12
6½	2·0	10·2	8·6	10·7	21·4	13
7	2·2	11·1	9·2	11·5	23·1	14
7½	2·4	11·9	9·9	12·3	24·7	15
8	2·5	12·7	10·5	13·2	26·4	16
8½	2·7	13·5	11·2	14·0	28·0	17
9	2·8	14·3	11·9	14·8	29·7	18
9½	3·0	15·0	12·5	15·7	31·3	19
10	3·2	15·8	13·2	16·5	33·0	20
10½	3·3	16·6	13·8	17·3	34·6	21
11	3·5	17·4	14·5	18·1	36·3	22
11½	3·6	18·2	15·2	19·0	37·9	23
12	3·8	19·0	15·8	19·8	39·6	24
12½	3·9	19·8	16·5	20·6	41·2	25
13	4·1	20·6	17·2	21·4	42·9	26
13½	4·2	21·4	17·8	22·3	44·5	27
14	4·4	22·2	18·5	23·1	46·2	28
14½	4·6	23·0	19·1	23·9	47·8	29
15	4·7	23·8	19·8	24·7	49·5	30
15½	4·9	24·5	20·5	25·6	51·1	31
16	5·0	25·3	21·1	26·4	52·8	32
16½	5·2	26·1	21·8	27·3	54·4	33
17	5·4	26·9	22·4	28·0	56·1	34
17½	5·5	27·7	23·1	28·9	57·7	35

RADII OF BOXWOOD CURVES.

Radius in Chains.	$\frac{1}{2500}$	$\frac{1}{500}$	Feet to an Inch.			
			50	40	20	33
18	5·7	28·5	23·8	29·7	59·4	36
18½	5·8	29·3	24·4	30·5	61·0	37
19	6·0	30·1	25·1	31·3	62·7	38
19½	6·2	30·9	25·7	32·2	64·3	39
20	6·3	31·7	26·4	33·0	66·0	40
20½	6·5	32·5	27·1	33·8	67·7	41
21	6·6	33·3	27·7	34·6	69·3	42
21½	6·8	34·1	28·4	35·4	71·0	43
22	6·9	34·9	29·1	36·3	72·6	44
22½	7·1	35·7	29·7	37·1	74·3	45
23	7·3	36·5	30·4	37·9	75·9	46
23½	7·4	37·2	31·0	38·8	77·8	47
24	7·6	38·1	31·6	39·6	79·2	48
24½	7·8	38·8	32·3	40·4	80·8	49
25	7·9	39·6	33·0	41·3	82·5	50
25½	8·1	40·2	33·6	42·1	84·1	51
26	8·2	41·3	34·3	42·9	85·7	52
26½	8·4	42·0	35·0	43·7	87·4	53
27	8·5	42·8	35·6	44·6	89·2	54
27½	8·7	43·6	36·3	45·4	90·7	55
28	8·9	44·4	37·0	46·3	92·4	56
28½	9·1	45·2	37·6	47·0	94·0	57
29	9·2	46·0	38·2	47·8	95·7	58
29½	9·3	46·8	38·9	48·7	97·3	59
30	9·5	47·6	39·5	49·5	99·0	60
30½	9·6	48·4	40·3	50·3	100·7	61
31	9·8	49·1	40·9	51·2	102·3	62
31½	9·9	49·9	41·6	52·0	103·8	63
32	10·0	50·6	42·4	52·8	105·5	64
32½	10·3	51·5	42·8	53·6	107·3	65
33	10·4	52·3	43·6	54·5	108·9	66
33½	10·6	53·1	44·3	55·3	110·5	67
34	10·8	53·9	44·7	56·2	112·2	68
34½	10·9	54·6	45·5	56·9	113·8	69
35	11·1	55·4	46·2	57·8	115·5	70
35½	11·2	56·2	46·8	58·6	117·2	71
36	11·4	57·0	47·5	59·4	118·8	72
36½	11·5	57·8	48·2	60·2	120·4	73
37	11·7	58·6	48·8	61·1	122·0	74
37½	11·9	59·4	49·5	61·8	123·7	75
38	12·0	60·2	50·3	62·7	125·4	76
38½	12·2	61·0	50·8	63·5	127·0	77

RADII OF BOXWOOD CURVES.

Radius in Chains.	$\frac{1}{2800}$	$\frac{1}{800}$	Feet to an Inch.			
			50	40	20	33
39	12·3	61·8	51·4	64·4	128·6	78
39½	12·5	62·6	52·2	65·2	130·3	79
40	12·7	63·4	52·7	66·0	131·9	80
40½	12·8	64·2	53·4	66·8	133·6	81
41	12·9	65·0	54·2	67·6	135·3	82
41½	13·1	65·8	54·7	68·5	136·9	83
42	13·3	66·6	55·4	69·3	138·5	84
42½	13·4	67·4	56·2	70·2	140·2	85
43	13·6	68·2	56·7	70·9	141·8	86
43½	13·8	68·9	57·4	71·7	143·4	87
44	13·9	69·7	58·1	72·6	145·2	88
44½	14·1	70·5	58·7	73·4	146·8	89
45	14·2	71·4	59·4	74·3	148·5	90
45½	14·4	72·2	60·0	75·1	150·1	91
46	14·6	72·9	60·7	75·9	151·8	92
46½	14·7	73·7	61·4	76·7	153·3	93
47	14·9	74·5	62·0	77·6	155·0	94
47½	15·0	75·3	62·7	78·4	156·6	95
48	15·1	76·1	63·4	79·2	158·2	96
48½	15·3	76·8	64·0	80·1	160·0	97
49	15·5	77·6	64·6	80·8	161·7	98
49½	15·6	78·4	65·3	81·7	163·2	99
50	15·8	79·2	66·0	82·5	165·0	100
50½	15·9	80·0	66·7	83·3	166·5	101
51	16·1	80·8	67·3	84·3	168·2	102
52	16·4	82·4	68·6	85 8	171·5	104
53	16·7	84·0	70·0	87·5	174·8	106
54	17·0	85·6	71·3	89·3	178·2	108
55	17·3	87·2	72·6	90·7	181·5	110
56	17·7	88·7	73·9	92·4	184·8	112
57	18·0	90·3	75·2	94·0	188·0	114
58	18·3	91·9	76·5	95·7	191·3	116
59	18·6	93·5	77·8	97·3	194·5	118
60	18·9	95·0	79·2	99·0	198·0	120
61	19·3	96·7	80·4	100·7	201·2	122
62	19·6	98·3	81·7	102·3	204·7	124
63	19·9	99·8	83·1	103·9	207·9	126
64	20·2	101·4	84·5	105·7	211·1	128
65	20·5	103·0	85·7	107·2	214·5	130
66	20·8	104·6	87·1	108·8	217·7	132
67	21·1	106·2	88·4	110·6	221·0	134
68	21·4	107·8	89·6	112·2	224·4	136

RADII OF BOXWOOD CURVES.

Radius in Chains.	$\frac{1}{2500}$	$\frac{1}{500}$	Feet to an Inch.			
			50	40	20	33
69	21·8	109·4	91·0	113·8	227·7	138
70	22·1	110·1	92·3	115·6	231·0	140
71	22·4	112·5	93·6	117·2	234·1	142
72	22·8	114·1	95·0	118·8	237·5	144
73	23·1	115·7	96·3	120·5	240·9	146
74	23·4	117·3	97·7	122·2	244·1	148
75	23·7	118·8	99·0	123·7	247·3	150
76	24·0	120·4	100·3	125·4	250·7	152
77	24·3	122 0	101·7	127·0	254·0	154
78	24·6	123·6	103·0	128·8	257·2	156
79	24·9	125·2	104·2	130 3	260·5	158
80	25·3	126·7	105·6	132·0	263·9	160
81	25·6	128·3	106·8	133·7	267·2	162
82	25·9	130·0	108·2	135·3	270·5	164
83	26·2	131·6	109·5	137·0	273·8	166
84	26·5	133·1	110·8	138·8	277·0	168
85	26·8	134·7	112·1	140·3	280·4	170
86	27·2	136·3	113·4	141·9	283·6	172
87	27·5	137·9	114·7	143·7	287·0	174
88	27·8	139·5	116·1	145·2	290·3	176
89	28·1	141·0	117·4	146·8	293·5	178
90	28·4	142·7	118·7	148·5	297·0	180
91	28·8	144·3	120·0	150·1	300·3	182
92	29·1	145·9	121·3	151·8	304	184
93	29·3	147·4	122·7	153·5	307	186
94	29·7	149·0	124·0	155·0	310	188
95	30·0	150·6	125·3	156·7	313	190
96	30·3	152·2	126·5	158 4	317	192
97	30·6	153·8	128·0	160·0	320	194
98	30·9	155·3	129·2	161·7	323	196
99	31·3	156·9	130·6	163·3	327	198
100	31·6	158·5	132·0	165·0	330	200
101	31·9	160·1	133·2	166 6	333	202
102	32·2	161·9	134·6	169·3	337	204
103	32·5	163·4	135·9	170·0	340	206
104	32·8	165·0	137·2	171·5	343	208
105	33·1	166·5	138·5	173·2	347	210
106	33·4	168·1	139·9	174·9	350	212
107	33·8	169·6	141·1	176·5	353	214
108	34·1	171·2	142·5	178·2	356	216
109	34·4	172·7	143·8	178·8	360	218
110	34·7	174·3	145·1	181·5	363	220

GALVANIZED IRON TELEGRAPH WIRE. (ARMCO QUALITY.)

Weight per mile Lbs.	Dia. ins.	Nearest S.W.G.	Breaking Load @25 tons Sq. In. Lbs.	Breaking Load Eng. St. Specn. Lbs. Min	Resistance in Ohms. 60° Fahr. Per Mile
1200	·296	1	3854	—	4·0
900	·256	3	2884	—	5·33
800	·242	3½	2576	—	6·0
750	·2325	4	2370	—	6·4
675	·2205	5	2140	—	7·1
600	·209	5¼	1930	1800	8·0
500	·191	6	1600	—	9·6
450	·181	7	1440	1350	10·66
400	·171	7½	1287	1200	12·0
350	·160	8	1126	—	13·7
300	·148	9	964	900	16·0
200	·121	10½	645	600	24·0
150	·105	12	485	450	32·0
100	·085	14	317	—	48·0
75	·074	15	241	225	64·0
60	·0657	16	185	—	80·0
50	·060	16½	159	—	96·0

The above Iron Galvanized Telegraph Wire conforms to the Specification of the Engineering Standards Committee, British G.P.O., India Office, Crown Agents, Dominion Government and Railway Specifications, both in mechanical and galvanizing tests.

In conductivity test, "Armco" Quality Ingot Iron Wire is guaranteed not to exceed a constant of 4800 (weight per mile in lbs. multiplied by resistance in ohms per mile at 60° Fahr.).

TABLE OF SIZES, WEIGHTS, LENGTHS AND

Diameter Inches	Size on Wire Gauge.	Diameter		Sectional area square inches.	Approxi-
		Decimal of an inch.	Milli-metres		100 yards
					lbs.
$\frac{1}{2}$	7/0	·500	12·7	·19635	200·11
$\frac{15}{32}$	6/0	·464	11·8	·16910	172·33
$\frac{7}{16}$	5/0	·432	11·0	·14657	149·37
$\frac{13}{32}$	4/0	·400	10·2	·12568	128·07
$\frac{3}{8}$	3/0	·372	9·4	·10869	110·80
$\frac{11}{32}$	2/0	·348	8·8	·09510	96·93
	1/0	·324	8·2	·08244	84·03
	1	·300	7·6	·07069	72·04
	2	·276	7·0	·05982	60·97
$\frac{1}{4}$	3	·252	6·4	·04987	50·85
	4	·232	5·9	·04227	43·07
	5	·212	5·4	·03530	35·97
$\frac{3}{16}$	6	·192	4·9	·02896	29·43
	7	·176	4·5	·02432	24·77
	8	·160	4·1	·02011	20·45
	9	·144	3·7	·01628	16·59
$\frac{1}{8}$	10	·128	3·3	·01287	13·12
	11	·116	3·0	·01057	10·80
	12	·104	2·6	·00850	8·63
$\frac{3}{32}$	13	·092	2·3	·00665	6·76
	14	·080	2·0	·00503	5·11
	15	·072	1·8	·00407	4·15
$\frac{1}{16}$	16	·064	1·6	·00322	3·29
	17	·056	1·4	·00246	2·50
$\frac{3}{64}$	18	·048	1·2	·00181	1·83
	19	·040	1·0	·00126	1·27
	20	·036	0·9	·00102	1·03
$\frac{1}{32}$	21	·032	0·8	·00080	·819
	22	·028	0·7	·00062	·628
	23	·024	0·6	·00045	·461
$\frac{3}{128}$	24	·022	0·55	·00038	·387
	25	·020	0·5	·00031	·320
	26	·018	0·45	·00025	·259
	27	·0164	0·4	·00021	·215
$\frac{1}{64}$	28	·0148	0·37	·00017	·175
	29	·0136	0·35	·00014	·148
	30	·0124	0·3	·00012	·123

BREAKING STRAINS OF STEEL WIRE.

Approximate Weight of		Approximate Length of		Approximate Breaking Strain	
Mile	Kilometre.	cwt.	100 kilos.	25 tons per square inch.	35 tons per square inch.
lbs.	lbs.	yards.	yards.	lbs.	lbs.
3522	2188	56	110	10995	15393
3033	1885	65	128	9469	13257
2629	1634	75	147	8208	11490
2254	1400	87·5	172	7035	9851
1950	1211	101	198	6086	8521
1706	1060	115	226	5326	7457
1479	919	133	261	4616	6463
1268	788	155	305	3958	5542
1073	667	183	360	3350	4690
895	556	220	433	2792	3910
758	471	260	512	2366	3313
633	393	311	612	1977	2767
518	323	380	748	1621	2269
436	271	452	890	1362	1908
360	224	546	1075	1125	1576
292	182	675	1329	911	1276
231	143	854	1681	720	1008
190	118	1040	2047	592	828
152	95	1293	2545	475	666
119	74	1653	3254	373	521
90	56	2186	4303	281	394
73	45	2699	5313	227	318
58	36	3416	6724	180	252
44	27·5	4462	8783	138	192
32·5	20·2	6073	11954	101	141
22·54	14·0	8745	17214	70	98
18·25	11·34	10796	21251	57	79
14·42	8·96	13663	26894	45	63
11·04	6·86	17846	35128	34·4	48·2
8·11	5·04	24290	47813	25·2	35·3
6·82	4·24	28908	56903	21·2	29·8
5·63	3·5	34978	68851	17·6	24·6
4·50	2·84	43184	85003	14·2	19·9
3·79	2·35	52021	102498	11·8	16·6
3·09	1·92	63877	125735	9·6	13·5
2·61	1·62	75646	148903	8·1	11·4
2·17	1·35	90996	179118	6·8	9·5

GALVANIZED IRON SIGNAL STRANDS AND STAY WIRES (ARMCO QUALITY). COMPOSED OF SEVEN WIRES.

Particulars of Strand.					Wire.				
	Diameter.								
S W.G Nominal	Ins. Nearest Fraction.	Decim.	M/M.	Nearest Circ. Ins.	Dia.	Nearest S.W.G.	Total Breaking Load. Lbs.	Appro. Wt. Per Mile. Lbs.	Length Per Cwt. Yds.
12	—	·104	2·64	$\frac{5}{16}$	·035	20	359	130	1520
11	$\frac{7}{64}$	·116	2·95	$\frac{3}{8}$	·039	19	446	160	1230
10	$\frac{1}{8}$	·128	3·25	—	·043	$18\frac{1}{2}$	532	195	1011
9	—	·144	3·65	$\frac{7}{16}$	·048	18	672	230	853
8	$\frac{5}{32}$	·160	4·06	$\frac{1}{2}$	·053	$17\frac{1}{2}$	811	292	675
8	$\frac{11}{64}$	·168	4·2	$\frac{9}{16}$	·056	17	918	323	610
7	—	·176	4·47	—	·059	$16\frac{1}{2}$	1011	351	560
6	$\frac{3}{16}$	·192	4·87	$\frac{5}{8}$	·064	16	1197	410	481
5	$\frac{7}{32}$	·212	5·38	—	·071	15	1477	520	379
4	$\frac{15}{64}$	·232	5·89	—	·077	$14\frac{1}{4}$	1729	610	323
4	—	·240	6·0	—	·080	14	1876	642	307
3	$\frac{1}{4}$	·252	6·40	$\frac{3}{4}$	·084	$13\frac{1}{2}$	2068	741	266
2	$\frac{9}{32}$	·276	7·01	$\frac{7}{8}$	·092	13	2480	850	232
1	$\frac{19}{64}$	·300	7·62	$\frac{15}{16}$	·100	$12\frac{1}{2}$	2926	963	205
1	$\frac{5}{16}$	·3125	7·93	1	·104	12	3165	1085	182
1/0	$\frac{21}{64}$	·324	8·23	—	·108	$11\frac{1}{2}$	3411	1211	162
2/0	$\frac{11}{32}$	·348	8·84	$1\frac{1}{16}$	·116	11	3937	1460	135
3/0	$\frac{3}{8}$	·372	9·45	$1\frac{1}{8}$	·125	10	4568	1650	120
4/0	$\frac{13}{32}$	·400	10·16	$1\frac{1}{4}$	·133	$9\frac{3}{4}$	5174	1822	108
5/0	$\frac{7}{16}$	·432	10·97	$1\frac{3}{8}$	·145	9	6146	2085	95
6/0	$\frac{15}{32}$	·464	11·79	$1\frac{1}{2}$	·155	$8\frac{1}{4}$	7036	2464	80
6/0	$\frac{31}{64}$	·480	12·2	$1\frac{1}{2}$	·160	8	7488	2646	73
7/0	$\frac{1}{2}$	·50	12·7	$1\frac{5}{8}$	·167	$7\frac{1}{2}$	8156	2840	69
7/0	—	·510	12·8	—	·170	$7\frac{1}{4}$	8454	2987	66
7/0	$\frac{17}{32}$	·528	13·41	—	·176	7	8971	3204	62

The Breaking Loads in the table are calculated at 25 tons per square inch. This represents the ultimate tensile strength in the annealed condition, which best resists corrosion.

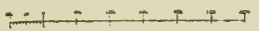
NOTES

in regard to the preparation of Railway Plans and Surveys, together with observations relating to the placing of Signalling thereon.

Each plan should have the title of the Railway Company placed thereon in full.

The North Point to show North upwards.

The Scale to be written and drawn



SCALES FOR PLANS AND SURVEYS.

8 feet to 1 inch.
20 feet to 1 inch.
1/500 full size or 41·66 feet to 1 inch } Ordnance
1/2500 full size or 208·33 feet to 1 inch } Scales.

Any exceptions to the above scales should be specially authorised before being used.

SCALES FOR DRAWINGS.

Brickwork Masonry and Steelwork—
$\frac{1}{8}$″ and $\frac{1}{4}$″ to 1 foot for general drawings.
$\frac{3}{8}$″, $\frac{1}{2}$″, $\frac{3}{4}$″ and 1″ for special details.

General drawings of all kinds of work should be drawn $\frac{1}{4}$″, $\frac{3}{8}$″, $\frac{1}{2}$″, $\frac{3}{4}$″ and 1″ to 1 foot, and special details $\frac{1}{8}$″ and $\frac{1}{4}$″ full size.

Railway Company's Existing Boundary to be edged with Pink.

Border Line.

The Assistant's initials and date of completion in right hand bottom corner of plan.

The number of plan or tracing to be in the right-hand corner, and the reference number of the papers, if necessary, in the top right-hand corner.

Where plans have to be signalled, the titles and all writing to be left blank until the Signals have been put on same.

With regard to Bridge calculations, areas of lands, etc. these must be checked and the Initials of both Assistants put on the drawing to ensure accuracy.

NOTES ON DRAWING, COLOURING, Etc.

Although each Railway Company has its own special rules laid down for colouring, etc., the following may be taken as being in fairly general vogue :—

General Plans : Main Lines Blue, with description Up, Down, Main, Fast, Slow, etc. with an arrow in 4 ft. to denote the direction of the traffic.

Sidings — Yellow.

Independents and Reception Sidings—Purple with description as stated for Main Lines.

Private Sidings—Green.

Brick and Stone buildings owned by the Railway Company—Indian Red.

Timber Buildings belonging to the Railway Company—Burnt Sienna etched with neutral tint.

Names of adjacent land owners to be given if possible.

Rivers, Ponds, Streams, etc.—Blue with an arrow denoting the direction of the flow.

Post and Rail Fences

Wrought and Paled Fences

Quick Set Hedges

Sleeper Fence with description.

Fence wall, large scale small scale with description.

Gates, single

Gates, double with direction of opening.

Cranes Capacity in Tons and maximum radius of jib to be stated.

Wheel Chocks

Buffer Chocks

Connected Points

Swing Chocks or Skotch Blocks

Water Columns

Signals to be shown and to lie in the direction of the traffic : exact position of base of post.

Weighing Machines to be marked W.M. ..... tons.

Description and size of Engine and Wagon Turntables to be given.

Small Details and Signals need not be shown on 1/2500 scale plans.

Insert at breaking off of running lines at each end of the plan :—

From (nearest principal station to left)

To (nearest principal station to right)

Mile posts to be shown with mileage, and all fixed points relative to the re-miling of the line.

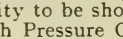
Gradient Boards to be shown :—

Roads and Carting Areas, light wash of Burnt Sienna, and the extent shown by Dotted Black Lines.

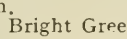
Names of roads to be given with from and to the nearest town or village.

Platform—Dark Burnt Sienna with description, Up or Down Platform, and stating if of wood, Concrete, Asphalte, Ash, Gravel, etc., and number if any.

Slopes—Shaded in Sepia.



Cutting (sloping towards Railway).



Embankment (sloping from Railway).

Gas Mains—Bright Green Lines. Position of meter and capacity to be shown in Bright Green.

High Pressure Gas Mains—Dotted Bright Green Lines.

Electric Mains—Purple Lines.

Water Mains—Blue Lines. Position of meter and capacity to be shown in Blue.

Hydraulic Mains—Dotted Blue Lines.

Oil Companies' Pipe Lines—Payne's Grey Dotted Lines. Whether pipes are above or below ground to be stated.

Drains—Burnt Sienna Lines.

Manholes, Valve Boxes, etc. size to be given.

Station Roofs or Awnings, etched with Dotted Black Lines.

Where Pipes, Sewers, Drains, Electric Hydraulic, Oil or Gas Mains pass under or over the Railway Company's property, they must be shown in their respective colours, and the reference to the Agreement noted thereon.

Proposed New Works—

Works to be removed—Dotted Black Lines.

New Works to be drawn and coloured Scarlet Lake.

Main Lines—Deep Scarlet Lake.

Independent Medium Scarlet Lake

Sidings—Pale Scarlet Lake.

Paving and Metalled Areas—Burnt Sienna, mixed with Crimson, with description written upon same, and the extent shown by Dotted Red Lines.

Additional Lands to be colour washed Scarlet Lake.

Proposed Company's Boundary, edged with Green.

In preparing New Surveys, the Drains, Traps, Manholes, Gullies, Gas and Water Pipes, and Valves should be marked and the positions of the Lamps shown upon the plan. The Drains to have an arrow showing the direction of their flow.

GENERAL SECTIONS AND CROSS SECTIONS:—

Excavation—Red

Filling—Green.

Rail Level—Blue Lines.

Datum to be fully described and position of datum point marked on the plan thus and, in all cases, to be Ordnance Datum.

STRUCTURAL DRAWINGS:—

	Elevation and plan	Section.
Brickwork	Light Red	Crimson and Burnt Sienna.
Blue Brick	Lamp Black and Blue	Same, deeper
Stonework	Yellow Ochre	Same, deeper
Concrete	Payne's Grey	Payne's Grey, mottled with White and Sepia.
Timber	Burnt and Raw Sienna	Same, grained.
Ironwork	Blue	Deep Blue.
Steelwork	Purple	Deep Purple.
Cast Iron	Neutral Tint	Same, Deeper
Ground Line	Sepia	Same, two shades.
Ballast	Lamp Black	Same, deeper.
Slopes,	Sepia Shaded	
Old Works	Light Wash of Lamp Black	Same, deeper.
Excavation		Red.
Filling		Green.

NEGATIVES:

To be drawn in full black lines, with thin black dimension lines.

Sections to be etched on negatives prepared for blue prints.

AGREEMENT PLANS:

To be prepared in duplicate without stamps or signatures. Work referred to shown in Red.

If a survey has to be "Signalled," and the Signal Box is decided to be fixed on the top side of the plan, the Signalling must be placed on the Survey the wrong way up; that is to say, the Signal Box be at the bottom of the plan, so that No. 1 Lever is at the left-hand side, just as the Signalman would be in the Cabin in readiness to pull his Levers.

Therefore it is essential that before plans are written up for the Board of Trade, the Signalling should be placed first thereon, so that all the writing is one way.

In rare instances, it is sometimes found necessary for a Signalman to pull off his Levers with his back to the line, say where the Railway is very tortuous.

In preparing surveys and new schemes for proposed lay-outs, the fact must always be borne in mind that spaces of at least 45 feet should be left between a pair of facing points and the next pair of points on the same line

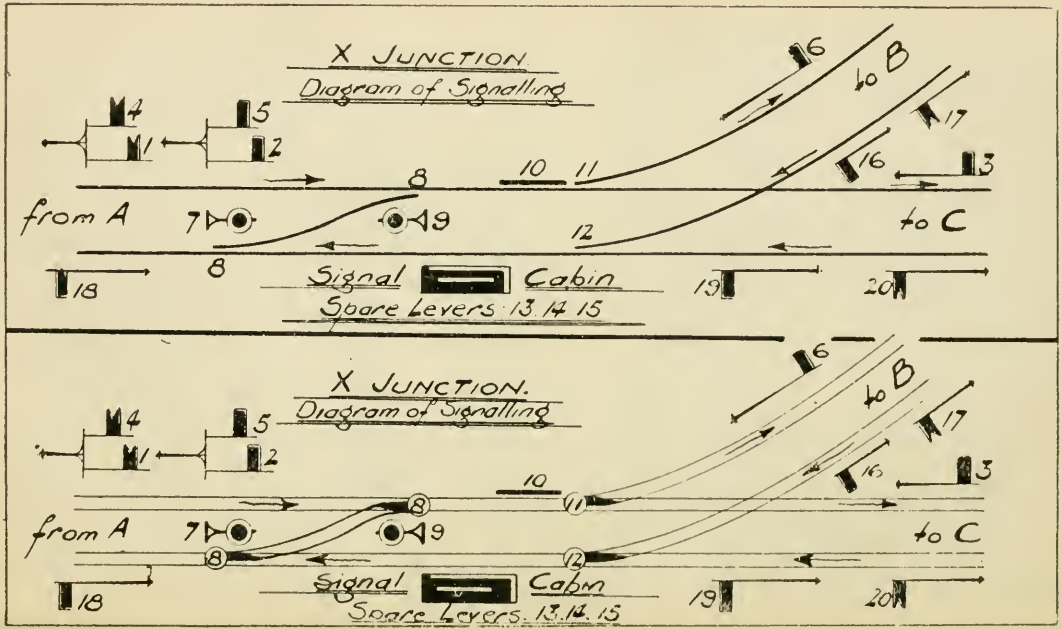
leading up to the former, so that locking bars may be readily fixed to the facing points; otherwise, if only a ten or twelve ft. space is left, it means that the locking bars have to be fitted along the switches, and this causes a great amount of complex arrangements which would be unnecessary, if the proper space were allowed for in the first instance.

All Signal Cabins must be provided with a diagram of the Signalling arrangements applicable to that installation, and each Company has its own standard sizes for these diagrams. These are of various dimensions, a useful size being 3 ft. 4 in. by 1 ft. 1½ in. and sample diagrams are shown hereunder.

Some Railway Companies use circles in which the numbers of the points are placed, whilst others leave out the circles, and exhibit a single line diagram, which, although not showing the lines in colour, yet has the advantage of presenting more clearly the normal position of the lay of the points.

The Apparatus Levers in the Signal Cabin should be painted according to the different connections they are operating, a good general standard being as follows:—

Levers Working:	Colour to be painted.
Distant Signals	Green
Stop Signals	Red
Points	Black
Locking Bars	Blue
Fouling Bars	Yellow
Economical Facing Point Locks	Top Half Blue: Bottom Half Black.
Gate Stops and Gate Locks	Top Half Black: Bottom Half Blue.
Gongs	Chocolate.
Fogging Machines	Top Half Red: Bottom Half Black.
Signal and Fogging Machine working together	Top Half Black: Bottom Half Red.
Spares	White.


X JUNCTION
Diagram of Signalling
4
1
5
2
8
10
11
16
to B
17
16
3
from A
7
9
12
to C
8
18
Signal Cabin
Spare Levers 13 14 15
19
20
X JUNCTION.
Diagram of Signalling
4
1
5
2
10
16
to B
17
16
3
from A
7
8
9
11
12
to C
8
18
Signal Cabin
Spare Levers. 13. 14. 15
19
20

VOCABULARY OF SIGNAL AND PERMANENT WAY DETAILS.

ENGLISH.	FRENCH.	SPANISH.	ITALIAN
Materials	**Materiaux**	**Materiales**	**Materiali**
Aluminium	Aluminium	Aluminio	Alluminio
Antimony	Antimoine	Antimonio	Antimonio
Asbestos	Asbeste	Asbesto	Amianto
Brass	Laiton	Latón	Ottone
Brickwork	Maçonnerie	Mamposteria	Muratura
Bronze	Bronze	Bronce	Bronzo
Concrete	Béton	Hormigón	Calcestruzzo
Copper	Cuivre	Cobre	Rame
Creosote	Créosote	Creosota	Creosoto
Glass	Verre	Vidrio	Vétro
Blue	Bleu	Azul	Azzúrro
Green	Vert	Verde	Vérde
Opal	Opaline	Opalina	Opalino
Orange	Orange	Amarillo (naranja)	Giallo (aráncia)
Red	Rouge	Rubio	Rósso
Signal	Verre d'écran	Vidrio de señal	Vétro dello schermo
White	Blanc	Blanco	Biánco
Gold	Or	Oro	Oro
Gravel	Gravier	Piedras	Ghiaia
Gun Metal	Bronze Rouge	Bronce rojo	Bronzo rósso
India Rubber	Caoutchouc	Caucho	Gomma
Iron	Fer	Hierro	Ferro
Cast	Fonte Moulé	Hierro fundido	Ghisa fusa
Cast Malleable	Fonte malleable	Fundición malleable	Ghiza malleabile
Wrought	Fer forgé	Hierromalleable	Ferro da fucina
Lead	Plomb	Plomo	Piombo

ENGLISH	FRENCH.	SPANISH.	ITALIAN.
Leather	Cuir	Cuero	Cuojo
Oil	Huile	Aceite	Olio
Phosphor Bronze	Bronze phosphoreux	Bronce fosfórico	Bronzo fosforoso
Platinum	Platine	Platina	Platina
Salt	Sel	Sal	Sale
Silver	Argent	Plata	Argento
Steel	Acier	Acero	Acciaio
Cast	Acier fondu	Acero fundido	Acciaio fuso
Crucible	Acier au creuset	Acero al crisol	Acciaio al crogiolo
Hard	Acier dur	Acero duro	Acciaio dúro
Mild	Acier doux	Acero blando	Acciaio blándo
Welding	Acier paur soudé	Acero soldado	Acciaio saldato
Stone	Pierres	Piedra	Pietra
Tin	Etain	Estaño	Stagno
Water	Eau	Agua	Acqua
Wood	Bois	Madera	Legna
Zinc	Zinc	Zinc	Zinco
Fastenings	**Moyen de fixation**	**Medio de sujeción**	**Mezzo d'attacco**
Bolt	Boulon	Tuerca y perno	Chia varda
Chain	Chaine	Cadena	Catena
Coach Screw	Tirefond	Tirafondo	Vite a legno
Cotter	Clavette	Chaveta	Chiavetta
Countersink	Fraisage	Fresado	Fresatura
Eye Bolt	Tige à œillet	Tornillo conojete	Vite ad occhiello
Gib	Crampon	Grapón	Rampicone
Gudgeon Pin	Tourillon	Perno de la cruceta	Perno d'articolazione
Hexagon Head	Hexagonal	Hexagonal	Testa esagonale
Lead Seal	Cachet en plomb	Precinto de plomo	Suggello di plombo
Lock Nut	Ecrou de sùreté	Fijado de tuerca	Sicurezza per viti

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Nut	Ecrou	Tuerca	Dado
Rag Bolt	Boulon de scellement	Tornillo para piedra	Bullone a mazzetta
Rivet	Rivet	Remache	Chiodo
Rivet Hole	Trou de Rivet	Orificio para el remache	Foro per chiodo
Screw	Goujon	Perno de sujeción	Prigioniero
Shackle	Moraillon	Estribo de sujeción	Staffetta di attacco
Shackle Bolt	Boulon à fourche	Peron con horquilla	Bullone aforcella
Snap Head Rivet	Tête bouterollé	Cabez de remache estampada	Testa ribadita
Split Link	Anneau fendu	Anillo hendido de acoplamiento	Gancio d'attacco
Split Pin	Goupille	Pasador	Copiglia
Spring Washer	Rondelle élastique	Arandela elástica	Rondella elastica
Thumb Screw	Vis de fermeture	Tornille de cierre	Vite di chiusura
Washer	Rondelle	Arandela	Rondella
Wood Screw	Vis à bois	Perno de sujeción para madera	Prigioniero a legno
Implements and Tools	**Utensiles et Outils d'exploitation**	**Utensilios y Herramientas**	**Attrezzi e Strumenti**
Auger	Tariere	Barrena	Trivella
Box Spanner	Clé à tirefonds	Llave para tirafondos	Chiave per vite a legno
Brazier	Brasier	Brasero	Bracere
Chisel	Ciseau	Cincel	Scalpello
Crow Bar	Anspect ou Levier	Espeque	Bastone a leva
Crown Drill	Perçoir à couronne	Broca de corona	Punta perforatrice a corona
Drill	Foret	Broca	Manico d'asta di fioretto
Field or Portable Forge	Forge portative	Fragua portátil	Fucina portatile
File	Lime	Lima	Lima
Hammer	Marteau	Martillo	Martello

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Measuring Tape	Décamètre à ruban	Metro de cinta	Nastro di misurazione
Monkey Wrench	Clef anglaise	Llave universal	Chiave inglese
Nippers	Tenailles	Tenazas de sujeción	Tenaglie
Oil Can	Bidon à graisse	Bidon para grasa	Bidone del grasso
Oil Feeder	Burette à huile	Aceitera	Siringa d'olio
Pinch Bar	Pince	Palanca	Leva
Plumb Bob	Fil à plomb	Plomada	Filo a piombo
Points Brush	Brosse pour aiguilles	Cepillo para agujas	Spazzola per scambi
Rail Plane	Rabot-lime pour Rails	Cepillo para carriles	Pialla per rotaie
Rail Square	Equerre de pose	Escuadra para la colocación	Squadra di posa delle rotaie
Rail Tongs	Tenailles à rails	Tenazas para carriles	Tenaglia per rotaie
Ratchet	Rochet	Sector dentado	Settore dentato
Saw	Scie à main	Serrucho	Seghetta a mano
Scraping Iron	Râcloir de joints	Rascador para juntas	Ferro per raschiare
Screw Driver	Tournevis	Destornillador	Cacciavite
Spirit Level	Niveau à bulle d'air	Nivel de burbuja	Livello ad acqua
Super-elevation Gauge	Règle de surhaussement	Patrón de peralte	Regolo di sopra-elevazione
Wire Cutting Nippers	Tenailles coupe fil	Tenazas corta alambre	Tenaglie taglia-filo
Signals and Accessories	**Signaux et Garnitures**	**Segales y Accesorios**	**Segnali ed Guarnitura**
Adjusting Joint	Fourche de reglage	Junta de regulación	Giunto di registro
Advance Signal	Signal avancé	Señal avanzada	Segnale avanzato
Arm	Bras	Brazo	Braccio
Arm Spindle	Axe de bras	Huso del brazo	Spiedo de braccio
Balance Lever for Signal Post	Levier de rappel de Signal	Palanca de inversión de la señal	Leva di richiamo del Segnale
Band	Bande	Cinta	Fascia
Barrel	Tambour	Cilindro	Tamburo
Basse of Signal	Base de Signal	Basa de Señal	Plinto di segnale

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Bracket Signal	Signal console	Señal con puntal	Segnale con listra
Burner	Bec	Mechero	Brucciatore
Cantilever Bracket Signal Post	Mât semaphorique à console	Poste semafórico de console	Semaforo ad un braccio ad aletta
Cap	Chapeau	Birreta	Tocco
Chimney	Verre	Chimenea	Cammino
Clearance Signal	Signal d'évacuation	Señal de despejo	Segnale disgombero
Disc Casting	Socle du disque	Fundición del disco	Fusione del disco
Distant Signal	Signal à distance	Señal adelantada	Segnale a distanza
Doll	Poteau	Poste corto	Antenna
Double Bracket	Double potence	Montante doble	Montante doppio
Downright Rod	Tringle de manœuvre	Varilla de tope	Asta d'arresto
Front Centre	Plaque d'assemblage	Plancha del assemblea	Lamièra de assemblea
Ground Disc Signal	Signal a disque fleur de sol	Señal de disco	Segnale a disco
Ground Dwarf Signal	Mât sémaphorique bas	Sémaforo enano	Antenna semaforica bassa
Half Bracket	Demi potence	Montante mitad	Montante metà
Handle	Manivelle	Mango	Manico
Hand Rail	Garde corps	Guardalado	Balustrata
Hand Rail Standard	Montante du Garde Corps	Conveniente de Guardalado	Convenévole di balustrata
Home Signal	Signal d'arrêt ou principal	Señal principal	Segnale principale
Inside Candle Stick	Manche du disque	Mango del disco	Mánico del disco
Inside Lamp	Lampe pour Intérieur	Linterna interior	Linterna interna
Iron Signal	Signal en fer	Señal de hierro	Segnale di ferro
Knob	Bouton	Bulto	Bózza
Ladder	Echelle	Escalera	Scala
Ladder Stay	Traverse de l'echelle	Estancia de escalera	Appoggiáre di scala
Lamp	Lanterne	Linterna	Lanterna
Lamp Exterior	Lanterne extérieure	Linterna exterior	Lanterna exteriore

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Lamp Interior	Lanterne intérieure	Linterna interior	Lanterna interna
Lamp Bracket	Support de lanterne	Soporte para linterna	Sostégno per lanterna
Lamp Hoist	Appareil de levage de lanterne	Ascensor para linterna	Sollevamento del fanale
Lamp Tray & Spindle	Plateau tournant	Plancha para vuelta	Lamina per giro
Lamp Winch	Treuil de lanterne	Torno de la linterna	Arganello del fanale
Lens	Lentille	Lente	Lente
Lens (Large)	Grande Lentille	Lente largo	Lente grande
Lens (Small)	Petite Lentille	Lente parte	Lente piccolo
Lower Quadrant Signal	Bras descendant	Brazo descendiente	Braccio discendente
Main Ladder	Grande echelle	Escalera largo	Scala grande
Oil Cistern	Cuvette de huile	Cisterna para aceite	Cisterna per Olio
Outside Lamp Case	Lanterne exterieure	Linterna exterior	Linterna esteriore
Pinnacle	Chapeau	Pináculo	Pinacolo
Point Indicator	Indicateur d'aiguilles	Indicador de cambio	Indicazióne di scambio
Reflector	Reflecteur	Reflector	Riflettore
Rod Guide	Guide de tringle	Guiar de varilla	Guidáre diasta
Route Indicating Signal	Signal indicateur de direction	Señal indicadora de dirección	Segnale indicatore del percorso
Shunting Signal	Signal de manœuvre	Señal de maniobra	Segnale di manovra
Signal	Signal	Señal	Segnale
Signal Bracket	Potence à signaux	Puntal de Señal	Beccatello di segnale
Signal Bridge	Passerelle à signaux	Puente para señales	Passerella dei segnali
Signal Crank	Equerre de signal	Palanca de señal	Leva del segnale
Signal post	Poteau de sémaphore	Poste del semáforo	Asta semaforica
Slotted Signal	Signal de consentement	Señal de consentimiento	Segnale di consenso
Spectacle	Ecran	Transparnte	Telaio
Spectacle (Back)	Ecran d'arrière	Transparente detras	Telaio diétro
Spectacle (Front)	Grande écran	Transparente largo	Telaio lárgo

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Spindle	Axe	Eje	Asse
Spindle Crank	Manivelle	Huso del palanca	Spiedo de leva
Stage	Palier	Escalon	Palco
Starting Signal	Signal de sortie	Señal de salida	Segnale d'uscita
Stop Signal	Signal d'arrêt	Señal de parada	Segnale d'arresto
Swing Bridge Signal	Signal de pont tournant	Señal de puente giratorio	Segnale di ponte girevole
Swivel Wheel	Galet pivotant	Voldana oscilante	Rotella girante su pernio
Target	Tableau	Escudo	Scúdo
Target Green	Tableau vert	Escudo verde	Scúdo vérde
Target Red	Tableau rouge	Escudo rubio	Scúdo rosso
Three Position Signal	Signal à trois positions	Señal de tres posicions	Segnale a tre posizione
Treble Bracket	Triple Potence	Montante triplice	Montante triplio
Tubular Steel Pole	Poteau en tube acier	Poste tubular de acero	Palo in tubi d'acciaio
Tunnel Signal	Signal de tunnel	Señal de túnel	Segnale di galleria
Two Position Signal	Signal à deux positions	Señal de dos posiciones	Segnale à due posizione
Upper Quadrant Signal	Bras montante ascendant	Brazo ascendiente	Braccio ascendénte
Wick	Mèche	Mecha	Lucignolo
Windlass Plate	Plaque de treuil	Plancha de torno	Lamina del argano
Wire Adjusting Screw	Tendeur de réglage	Aparato tensor de cable	Apparecchio tenditore del filo
Wire: Galvanized Steel, 7 strands	Cable ou fil en acier, 7 forons	Alambre de acero, 7 giro	Filo d'acciaio, 7 giro
Wire: Solid or Single Strand	Cable ou fil en acier: solide	Alambre de acero sólido	Filo d'acciaio sólido
Wood Signal	Signal en bois	Señal de madera	Segnale di legna
Wood Slat	Plancher de bois	Piso de madera	Paviménto di legno
Interlocking Apparatus	**Appareil d'enclenchement**	**Aparato de cierre**	**Apparecchio di chiusura**
Catch Box	Boite de ressort de la manette	Corredera-guia del fiador	Pezzo di guida del paletto

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Catch Link	Attaché de la poignée à ressort	Adherencia de mango de resorte	Aderénza della impugnatura del molla
Catch Rod	Tige à ressort	Varilla del resorte	Asta del molla
Catch Rod Thimble or Knuckle	Ecrou de réglage	Tuerca de regulación del fiador	Madrevite di regolazione dell asta del paletto
Check Locking	Enclenchement pour échec	Enclavamiento para restricción	Chiusura per impediménto
Dog Chart or Locking Table	Tableau des enclenchements	Tabla de los enclavamientos	Diagramma di cottegamento di chiusura
Flattened Shaft, Locking	Enclenchement avec arbre à méplat	Enclavamiento con arbol aplanado	Chisura a catenaccio con albero applattito
Front Tail Lever	Barre de transmission	Barra de transmision	Sbara della transmissione
Interlocking Frame	Appareil d'enclenchement	Aparato de maniobra para señales y agujas	Apparecchio di manovra per segnale e scambio
Interlocking Gear	Régistre d'enclenchement	Régistro de enclavamiento	Registro di chiusura
Interlocking Point	Contrepoids compensateur de transmission rigide	Contrapeso compensador de la transmisión rigida	Contrappeso della transmissione rigida
Lever Balance Weight	Attaché à gauche de la barre d'enclenchement	Adherencia siniestro de barra de enclavamiente	Aderénza sinístro della shara della chiusura
Lever Link, Left Hand	Attache à droit de la barre d'enclenchement	Adherencia recto de barra de enclavamiento	Aderénza déstro della sbara della chiusura
Lever Link, Right Hand	Sabot du lévier	Pieza de unión de la palanca de maniobra	Pezzo di raccordo
Lever Shoe	Barre d'enclenchement longitudinale	Barra de enclavamiento longitudinal	Sbarra di chiusura longitudinale
Locking Bridle	Appareil de manœuvre à tringles	Aparato de maniobra con barras	Apparecchio di concando ad aste
Locking Frame for Rod Gear	Appareil de manœuvre à fil de transmission	Aparato de maniobra con alambre transmisor	Apparecchio di manovra à filo
Locking Frame for Wire Gear			

ENGLISH.	FRENCH.	STANISH.	ITALIAN.
Locking Lever	Levier d'enclenchement	Palanca de enclavamiento	Leva di chiusura
Locking Tray	Boîte des organes d'enclenchement	Caja de los órganos de cierre	Cassa delle chisure
Locking Trough	Case d'enclenchement	Receptáculo de cierre	Truógo di chiusura
Plunger Lock	Enclenchement de la touche	Parada del botón	Arresto del tasto
Point Lever	Levier d'aiguillage	Palanca del sistema de agujas	Leva dello scambio
Quadrant	Secteur	Sector	Settore
Quadrant, Left Hand	Secteur extrème côté gauche	Sector siniestro	Settore sinístro
Quadrant, Middle	Secteur intérmédiare	Sector intermedio	Settore mezzáno
Quadrant, Right Hand	Secteur extrème côté droit	Sector recto	Settore déstro
Rocker	Bascule oscillante	Sector oscilante	Leva di oscillazione
Rocker or Shaft, Locking	Enclenchement à arbres	Enclavamiento por árboles	Chiusura ad albéro
Rotation Locking	Enclenchement de rotation	Enclavamiento para rotación	Chiusura ad rotazióne
Self-Locking	Enclenchement pour soi-même	Enclavamiento para mismo	Chiusura per medesimo
Spring	Ressort	Resorte	Molla
Spring Catch	Manette à ressort	Fiador de resorte	Impugnatura a molla
Spring Catch, Upright Lever	Lévier simple à ressort	Palanca vertical	Leva verticale
Tappet Lock	Taquet d'enclenchement	Taco de enclavamiento	Tacco di chiusura
Tappet Locking	Enclenchement à taquets	Enclavamiento por tacos	Chiusura a tacco
Thick Plunger	Barre d'enclenchement du levier	Corredera do enclavamiento de la palanca	Chiavistello della sbara della leva
Thin Plunger	Barre d'enclenchement de la poignée	Corredera de enclavamiento de mango	Chiavistello della sbara del impugnatura

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Gate Gearing	**Materiaux pour Barrieres**	**Materiales para Barreras**	**Materiali per Barriera**
Gates	Barrières	Barreres	Barriera
Gate Closing, Mechanism	Appareil d'arrêt pour barrières	Aparato de detención para barreras	Catenaccio per barriera
Gate Crab or Winding Gear	Chevalet de treuil	Caballete de cabria	Cavalletto ad arganello
Gate Lamp	Lanterne pour barrière	Linterna para barrera	Lanterna di barriera
Gate Post	Poste de barrière	Posta de barrera	Posta di barriera
Gate Locks	Verrous pour barrières	Enclavamiento para barrera	Chiusura per barriera
Gate Rodding	Transmissions rigides pour barrières	Varill para barrera	Asta di barriera
Gate Rod Rollers	Galets pour transmissions rigides pour barrières	Roldanas para barrera	Rulli per barriera
Gate Screw	Ecrou pour barrière	Tornillo para barrera	Vite di barriera
Gate Stops	Obstacles pour barrières	Obstáculo para barrera	Ostácolo per barriera
Gate Target	Targe de barrière	Rodela de barrera	Bersaglio di barriera
Gate Wheel	Roue pour barrière	Rueda para barrera	Ruóta di barriera
Hand Worked Gates	Barrières manœuvrées à la main	Barrera maniobrada a mano	Barriera manovrate a mano
Lifting Gate or Barrier	Barrière à bascule	Barrera levediza	Barriera levatoia
Mechanically Worked Gates	Barrières manœuvrées à distance	Barrera accionada á distancia	Barriera con chiusura a distanza
Pinion	Pignon	Piñon	Punta
Rack	Crémaillère	Rueca	Ruota
Red Shield	Tableau rouge	Escudo rubio	Scúdo rósso
Wicket Gate	Guichet de barrière	Postigo de barrera	Sportello di barriera
Ground Fittings	**Garniture pour Transmission de fleur du sol**	**Equipo para Transmisión de Tierra**	**Guuarnitura per transmissione del Terra**
Accommodating Crank	Équerre à branche courbe	Palanca arqueada	Leva arcuata

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Acute Crank	Équerre à angle aigu	Palanca ángulo agudo	Leva angolo acúto
Adjusting Crank	Équerre de réglage	Escuadra de regulación	Squadra di registro
Adjusting Screw	Vis de réglage	Tornillo de graduación	Vite regolatrice
Angle Pulley Wheel	Poulie mobile	Polea para oscilación	Puléggia per oscillazióne
Ball bearing	Support à billes	Soporte de bolas	Sopporto a sfere
Base Plate	Plaque de fondation	Placa de cimentación	Piastra di fondazione
Bell Crank Compensator	Équerre de compensateur	Esquadra compensadora	Leva a squadra compensa-
Bent Crank	Levier en forme de faucille	Palanca en forma falciforme	Leva a falce [trice
Channel Rodding	Transmission en fer [	Varillas en [	Asta in ferro ad [
Cover Bolt Lock Casting	Couvercle de la boîte du verrou	Cubierta de caja de enclava	Copérchio del cassa di chiusura
Crank	Équerre	Palanca	Squadra
Cross Slide of Bolt Lock	Tringle d'enclenchement	Barra de enclavamiento	Sbarra di chiusura
Escapement Crank	Levier coudé de déclenchement	Manivela de desenclavamiento y enclavamiento	Manovella codata di aperturaó di liberazione e di chiusura
Eye Joint	Raccord avec œil ou piton d'articulation	Armella de unión	Occhiello di collegamento
Facing Point Lock	Verouillage d'aiguille	Enclavamiento aguja	Chiusura con lucchetto
Forked Crank	Équerre à fourchette	Palanca en horquilla	Leva a forchetta
Gas Rodding	Tuyau à gaz	Tubo de gas	Tubo per gas
Goose Neck	Col de cygne cintre	Cuello de cisne arco	Cóllo del cigno arcáto
Hanging Wheel	Poulie pendante	Polea suspensión	Puleggia sospensióne
High Crank	Equerre type haut	Palanca alto	Leva alto
Hollow Rodding or Piping	Transmission rigide, tube	Varilla tubular	Asta tubolare
Horizontal Compensator	Compensateur horizontale	Compensador horizontal	Compensatore orizzónte
Horizontal Wheel Frame	Support pour poulie horizontale	Soporte para polea horizontal	Sostégno per puleggia orizzónte

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Intermediate Compensator	Compensateur intermédiare	Compensador intermedio	Compensatore intermedia
Iron Stake	Piquet en fer	Poste de hierro	Pósta di ferro
Joint	Chape	Junta	Giuntúra
Large Roller	Grande poulie de transmission	Polea largo de transmisión	Rulli grande di transmissione
Link	Bielle	Cadena	Caténa
Locking Bar	Latte de calage, ou Pédale d'enclenchement	Pedal de enclavamiento	Sbarra di chiusura longitudinale
Lockiug Bar Clip	Coussinet de latte de calage	Biele de pedal de enclavamiento	Manovella del pedale di incatenamiento
Locking Bar Stop	Taquet d'arrêt de la pédale	Tope de detención del pedal	Pezzo d'applicazione del pedale
Long Jaw or Forked Joint	Chape prolongée	Palanca en horquilla	Leva a forchette
Low Crank	Équerre, type bas	Palanca bajo	Leva básso
Medium Crank	Équerre, type moyen	Palanca medio	Leva mézzo
Narrow Joint	Chape étroite	Palanca en estricho	Leva a stretto
Obtuse Crank	Equerre à angle obtus	Palanca ángulo obtuso	Leva angolo ottúso
Pedestal Crank	Equerre de verticale	Palanca de vertical	Leva a verticale
Pedestal Wheel Frame	Support pour poulie verticale	Soporte para polea vertical	Sostégno per puleggia verticále
Pipe Rodding	Tringle tubulaire pour transmission	Varilla tubular	Asta tubolare
Plunger Casting	Douille de guidage, de la tige de verrou	Manguita de guja del perno del cerrojo	Scatola di guida dell asta del catenaccio
Plunger Lock	Verrou d'aiguille	Enclavamiento por regleta	Collegamento a catenaccio
Point Connections	Changements de voie	Cambios de via	Scambi di vie

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Point Lock Lever	Levier de manœuvre du verrou	Aparato de maniobra de las agujas	Apparecchio di manovra dello scambio
Point Rod with Plug, Rivet and Cotter	Tuyau complète avec goujon, rivet, et clavette	Varilla con tapón, remache y chaveta	Asta con tappo chiodo e chiavetta
Point Rod Connection	Tringle de connexion rigide	Varilla de conexión	Asta di unione degli aghi
Point Rod Roller	Support de poulie de transmission	Soporte de las roldanas de transmisión	Sedia a rulli portanti di transmissione
Poker Bolt Lock for Ground Disc	Verrou pour disque à fleur de sol	Enclavamiento para señal de disc	Chiusura per segnale a disco
Poker Bolt Lock Casting	Boîte du verrou	Caja de enclavamiento	Cassa di chiusura
Radial Crank	Levier pour renvoi d'angle, ou genouillère	Palanca para cambio de dirección en angulo	Leva deviazione
Rocking Shaft	Arbre intermédiare	Arbol intermedio	Albero di rimando
Roller Segment	Support de poulie de transmission	Soporto de polea de transmisión	Sostégno di rulli di transmissione
Side Pulley Wheel	Poulie fixe	Polea de cambio	Puleggia di cambiamento
Skotch Block	Sabot d'arrêt	Taco	Scarpa di fermeta
Sleeve Joint	Manchon	Union	Collegamento
Slot in Rod	Mortaise de tringle	Estribo de varilla	Finestra dell' asta
Small Roller	Petite poulie de transmission	Polea parte de transmisión	Rulli piccolo di transmissione
Solid Rodding	Transmission solide	Varilla maciza	Asta piena
Spacing Piece	Pièce de connexion de poulie de transmission	Varilla de conexión de polea de transmisión	Asta di unione del rulli di transmissione
Star Crank	Équerre d'étoile	Palanca en estrella	Leva a stella
Straight Arm Compensator	Balancier Compensateur	Balancin Compensador	Bilanciere compensatore
Strap	Étrier	Correa	Coréggia
Swan Neck	Col de cygne de recourbé	Cuello de cisne inclinación	Cóllo del cigno inclinato

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Tang end	Extrémité à soudée	Extremo macizo de una varilla	Estremo masficcio di rinforzo di un asta
Trunking in Cast Iron	Caniveau en fonte	Canal de fundición	Cunicolo di ghisa
Trunking in Wood	Caniveau en bois	Canal de madera	Cunicolo di legno
Turnbuckle	Boucle de fil	Bucle del alambre	Finestra del filo
Turnover Skotch Block	Taquet basculant	Taco basculante	Scarpa capovolgibile
Vertical Compensator	Compensateur verticale	Compensador vertical	Compensatore verticále
Vertical Crank	Retour d'équerre verticale	Palanca vertical	Leva verticále
Wheel	Poulie	Polea	Puleggia
Wood Stake	Piquet en bois	Poste de madera	Pósta di legno
Permanent Way Fittings	**Garnitures pour la Voie**	**Equipo para la Via**	**Guarnitura per la Via**
Bull Head Rail	Rail à double champignon	Carril de doble cabeza	Rotaia a doppio fungo dissimetrico
Chair	Coussinet de rail	Cojinete de carril	Cuscinetto di rotaia
Check Rail	Contre rail	Contracarril	Contro rotaia
Coach Screw	Tire fond	Tirafondo	Vite a legno
Fang Bolt	Boulon d'ancrage passant	Perno de anclaje passante	Bullone traversante
Ferro-Concrete Sleeper	Traverse en béton armé	Traviesa de hormigón armado	Traversina in cemento armato
Fish Plate	Éclisse	Brida	Stecca
Fish Plate Joint	Éclissage	Embridado	Giunto a stecche
Flat Bottom Rail	Rail Vignole	Carril Vignole	Rotaia Vignole
Key	Coin	Cuña	Cuneo
Pull-over Lever	Levier de manœuvre	Palanca de maniobra	Leva di manovra
Rail	Rail	Carril	Rotaia
Sleeper	Traverse	Traviesa	Traversina
Sole Plate	Semelle de rail	Chapa para el peralte	Grossezza sottoposta
Spike	Crampon	Escarpia	Arpione
Spring Tongue or Switch	Aiguille flexible	Aguja elástica	Ago elastico

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Steel Sleeper	Traverse en acier	Traviesa de acero	Traversina d'acciaio
Straight	Alignement	Alineación	Tratto
Stretcher Rod	Tringle de connexion	Varilla de conexión	Asta di unione degli aghi
Switches	Aiguillages	Agujas	Scambi
Switch Blade	Aiguille de changement de voie	Aguja de cambio de via	Ago dello scambio
Switch End	Extrémité du changement	Talón del cambio	Calcio dello scambio
Switch Heel	Centre du changement	Centro del cambio	Centro dello scambio
Trenail	Cheville de Coussinet	Clavija de cojinete	Chiodo per cuscinetto
Wood Sleeper	Traverse en bois	Traviesa de madera	Traversina in legno
Building and Surveying Terms in connection with the construction of Permanent Way and Signalling			
Ballast	Ballastage	Capa de balasto	Massiciata
Bank	Talus	Talud	Scarpa
Brick Signal Cabin	Cabin de maçonnerie	Garita de mamposteria	Cabina di muratura
Brick and Wood Signal Cabin	Cabin de maçonnerie et bois	Garita de mamposteria aun madera	Cabina di muratura ed legna
Boundary	Frontière	Frontera	Limite
Camber	Flèche	Flecha	Freccia
Cant of Rail	Déversement du rail	Acción de carril	Rovesciamento della rotaia
Clearance Gauge	Gabarit de profil normal	Gálibo de perfil normal	Profilo dello spazio libero
Contraction	Contraction	Contracción	Contrazióne
Converging Line	Point de rencontre	Punto de encuentro	Punto di mèta
Crank Foundation	Support d'équerre	Soporte de la escuadra de cambio de dirección	Sostegno delle squadre
Creep of Rails	Marche de Rails	Desplazamiento de los carriles	Scorrimento delle rotaie
Cupboard	Armoire	Armario	Armario
Curve	Courbe	Curvatura	Curve
Cutting	Déblai	Desmonte	Sterro

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Deflection	Flexion	Flecha	Flessione
Diamond Crossing	Croisement oblique	Cruzamiento oblicuo	Incrocio ad angolo acuto
Double Slip	Traversée-jonction double	Transversal de unión doble	Deviatoio inglese doppio
Drainage	Drainage	Drenaje	Drenaggio
Earthwork	Infrastructure	Infrastructura	Sottostruttura
Embankment	Remblai	Terraplén	Rilevato
Expansion	Dilatation	Dilatación	Dilatazione
Fencing	Clôture	Cerca	Chiusúra
Floor	Plancher	Piso	Pavimento
Floor Joist	Traverse de plancher	Travasaño del piso	Traversa del pavimento
Flying Junction	Jonction provisoire	Bifurcación provisional	Biforcazione provisoria
Foundation	Support	Soporte	Sostegno
Gauge	Largeur de voie	Anchó de la via	Scartamento
Broad	Voie large	Via ancha	Scartamento largo
Metre	Voie d'un mètre décartement	Via de un metro de ancho	Scartamento di un metro
Narrow	Voie étroite	Via estrecha	Ferrovia a scartamento ridotto
Standard	Voie normale	Via normal	Scartamento normale
Gradient	Rampe	Rampa	Rampa
Ground Level	Niveau du sol	Llana del tierra	Livéllo del térra
Halt (Roadside Station)	Point d'arrêt	Parada	Fermata
Hedge	Haie de clôture	Cerca de setos	Chiusura di siepi
Instrument Shelf	Planche pour appareils	Bajío para aparato	Tavola del apparecchio
Leading-out	Tiges de traversées	Vástagos de paso	Aste di trazione attraversanti
Loading Gauge	Gabarit de chargement	Plantilla de carga	Sagoma limite
Locker	Placard	Armario	Cassone

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Lubrication	Graissage	Engrase	Lubrificazione
Mileage	Distance de transport	Longitud de transporte	Distanza di trasporte
Opening for Rods and Wires	Ouverture de passage pour transmissions	Paso de pared para transmisión	Attraversamento del muro per transmissióne
Overbridge	Passage par dessus	Paso superior	Cavalcavia
Permanent-Way	Voie	Via	Scartamento
Platform	Quai	Andén	Banchina
Rail Level	Niveau du rail	Cara superior del carril	Spigolo superiore della rotaia
Rail Section	Profil de rail	Perfil del carril	Profilo di rotaia
Railway Junction	Embranchement	Unión de ferro-carril	Raccordo di ferrovia
Scissors Crossing	Jonction double	Comunicación doble	Incrocio doppio
Single Slip	Traversée-jonction simple	Transversal de unión sencilla	Deviatoio inglese semplice
Six-foot Way	Entre-voie	Entre via	Intervallo dei binari
Skew Level Crossing	Passage à niveau biais	Paso à nivel oblicua	Passaggio a livello sbieco
Slueing of Rail	Déplacer les rails	Desplazar les carriles	Spostare le rotaie
Speed	Vitesse	Velocidad	Velocità
Staggering of Holes	Placer les trous de part et d'autre	Disponer los agujeros en zig-zag	Spostare i fori simmetricamente rispetto all'asse
Station	Gare	Estación	Stazione
Straight Level Crossing	Passage à niveau rectangulaire	Paso á nivel rectangular	Passaggio a livello rettangolare
Stool	Escabeau	Silla	Sedia
Subway	Tunnel en dessous du niveau du sol	Túnel subterráneo galeria nel sottosuelo	Galleria sotterranea
Super-elevation of Rails	Surhaussement des Rails	Sobre-elevación de los carriles	Sopraelevazione della rotaia
Supported Rail Joint	Joint appuyé	Junta apoyada	Giunto protato

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Suspended Rail Joint	Joint en porte-à-faux	Junta al aire	Giunto libero
Tangent	Tangente	Tangente	Tangente
Timbering	Boisage	Entibación	Armatura a cassa
Transition Curve	Courbe de raccordement	Curva de enclace	Curva di raccorde
Tunnel	Tunnel	Túnel	Galleria
Underbridge	Passage par dessous	Paso inferior	Sottovia
Water Column	Colonne de grue	Columna de la grua	Colonna della gru
Wood Signal Cabin	Cabin de bois	Garita de madera	Cabina di legna
Miscellaneous Terms and	**Means used in connection**	**with Permanent-Way and Signalling.**	
Absolute Block	Block absolu	Block absoluto	Blocco assoluto
Alarm Signal	Signal d'alarm	Señal de alarma	Segnale d'allarme
Audible Signal	Signal acoustique	Señal acústica	Segnale acustico
Bell Code	Code de sonnerie	Reglamento de llamada	Regolamento d'allarme
Bell Signal	Signal par cloche	Señal con campana	Segnale a campana
Boxing-in	Caniveau des transmissions	Canal de transmisión	Cunicolo della transmissione
Branch Line	Embranchement voie déviée	Via lateral	Binario laterale
Block Section	Section de Block	Sección del Block	Sezione di blocco
Block Signal	Signal de Block	Señal del Block	Sengale di blocco
Caution Signal	Signal de ralentissement	Señal de entrada con precaución	Segnale di rallentamento
Caution Working	Service d'avertissement	Servicio de entrada con precaución	Movimento di avviso
Clear Signal	Signal de marche	Señal de via libre	Segnale di via libera
Compensation	Compensation	Compensación	Compensazione
Counterbalance	Contrepoids	Contrapesar	Contrappeso
Crossing Loop	Point d'évitement	Punto de apartadero	Punto di scambio dei treni
Current	Courant	Corriente	Corrente

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Danger Signal	Signal de danger	Señal de peligro	Segnale di pericolo
Double	Double	Doble	Doppio
Double Line Working	Service de voie double	Servicio doble	Movimento doppio
Earth	Terre	Tierra	Terra
Fast Line	Voie à trains rapides	Via para trenes rápidas	Ferrovia con treni direttissimi
Flag Signal	Signal par le drapeau	Señal hecha con el banderin	Segnale a bandiera
Fog Signal or Detonator	Pétard	Petardo	Petardo
Fog Signalman	Surveillant en temps de brouillard	Vigilante en tiempo de niebla	Sorvegliante in tempo di nebbia
Fixed Signal	Signal fixe	Señal fija	Segnale fisso
Hand Lamp	Lanterne à main	Linterna de mano	Lanterna a mano
Hand Signal	Signal à main	Señal de mano	Segnale a mano
Interchangeability	Échangeable	Alternar	Scambiévole
Light Signal	Signal lumineux	Señal luminosa	Segnale luminoso
Lever half-way	Position intermédiare du lévier de manœuvre	Posición intermedia de la palanca de maniobra	Posizíone media della leva di manovra
Lever normal	Position normal du lévier de manœuvre	Posición normal de la palanca de maniobra	Posizíone regoláre della leva di maniobra
Lever over	Position extrêma du levier de manœuvre	Posición extrema de la palanca de maniobra	Posizíone estrema della leva di manovra
Lever reversing	Renverser le lévier de manœuvre	Invertir la palanca de maniobra	Invertire la leva di manovra
Loop Line	Voie de garage	Apartadero de la via	Scambio del binario
Main Line	Voie principale	Via principal	Binario principale
Mechanical Signal	Signal mécanique	Señal mecánica	Segnale meccanico
Metallic Return	Conducteur nu de retour	Alambre de retorno	Filo di ritorno metallico
Multiple	Multiple	Multiplice	Moltiplice
Negative	Sous-volteur (Négatif)	Negativo	Devoltore (Negatíva)

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Octuple	Octuple	Ottuplo	Ottuplo
Passing Place	Point d'évitement	Punto de apartadero	Punto di scambio dei treni
Permissive Block	Block permissif	Block á voluntad	Blocco permissivo
Positive	Positif	Positivo	Positívo
Quadruple	Quadruple	Cuadruplo	Quadruplo
Quintuple	Quintuple	Quintuplo	Quintuplo
Reversing Triangle	Triangle de raccordement	Triángulo de union	Triangolo di raccordo
Signalling Regulations	Instruction rélatif aux signaux	Instrucción relativa á los señales	Istruzione relative ai segnali
Safety Switch	Aiguille de sûreté	Aguja de seguridad	Scambio di sicurezza
Septuple	Septuple	Settuplo	Settuplo
Sextuple	Sextuple	Séstuplo	Sestuplo
Shunting	Mouvements	Movimentos	Movimento
Siding	Voie latérale	Via lateral	Binario secondario
Signal Cabin Diagram	Schema des signaux et de la voie	Schema del señals y portante	Esquema di Segnales de la via
Signal Connections	Transmission des manœuvres	Transmisión de maniobra	Transmissione di manovra
Signal Cabin	Cabin de poste de manœvrue	Garita de la estación de maniobra	Cabina di manovra
Signal Flag	Drapeau signal	Banderin de señales	Bandiera da segnali
Signalman	Signaleur	Señalador	Segnalatore
Single	Simple ou Unique	Simple	Singolare o único
Single Line Working	Service de voie unique	Servicio una via	Movimento singolo
Slow or Goods Line	Voie des wagons à marchandises	Via para vagones de mercanías	Binario per merci
Stroke of Lever	Angle décrit parle lévier	Angulo describido por la palanca	Rotazione della leva
Signal Light	Feu de Signal	Luz de la señal	Luce del Segnale

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Slueing of Rails	Déplacer les Rails longitudinalement	Desplazar los carriles longitudinalmente	Spostare le rotaie longitudinalemente
Through Line Working	Service de voie libre	Vid de tráfico libre	Binario di passaggio
Tightening to Gauge	Rétrécissement de la voie	Estrechamiento de la via	Restringimento del binario
Through Shunt or Cross-over Road	Rail de jonction	Via de enclace	Binario di allacciamento
Treble	Triple	Triplice	Triplo
Visual Signal	Signal optique	Señal de vista	Segnale ottico
Zero	Zéro	Cero	Zero
Whistle	Sifflet	Silbato	Fischietto
Widening to Gauge	Enlargissement de la voie	Ensanchamiento de la via	Allargamento del binacio
Electrical Signalling Apparatus	**Appareil Électrique pour Signalisation**	**Aparato Electrica para Señales**	**Aparecchio Elettricamente per Segnali**
All-Electric Power Plant	Appareil de manœuvre électrique	Aparato de maniobra eléctrico	Apparecchio di manovra elettrico
Automatic Signal	Signal automatique	Señal automática	Segnale automatico
Battery	Batterie	Bateria	Batteria
Bell	Cloche	Campana	Campana
Block Instrument, One Wire, Three Indication, Alternating Current, Tyer's System	Appareil de Bloc Tyer, avec courant alternatif	Aparato de Block Tyer, con corriente alterna	Apparecchio di Blocco, Tyer con corrente alternata
Block Instrument, One Wire, Three Indication, Direct Current, Tyers System	Appareil de Bloc Tyer, avec courant continu	Aparato de Block Tyer con corriente continua	Apparecchio di Blocco Tyer con corrente continua
Block Instrument, Permissive Indicating Tyer's System	Appareil de Bloc Tyer, avec indication permissif	Aparato de Block Tyer, con indicación permissivo	Apparecchio di Blocco Tyer can indicazione, permessivo

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Cab Signal	Signal de la cabine du conducteur	Señal del garita del conductor	Segnale di cabina de conduttore
Contact	Extrémité	Extremidad	Estremità
Commutator	Commutateur	Commutador	Commutatore
Detector, Electrical	Contrôle electrique	Registro, eléctrico	Controllo elettrico
Electro-Pneumatic Power Plant	Appareil de manœuvre à pneumatique et regulation électrique	Aparato de maniobra de neumático y regulación eléctrica	Apparecchio di manovra pneumatico e regolato elettricamente
Fouling Bar, Electric Hydraulic Power Plant	Appareil de manoeuvre hydraulique	Aparato de maniobra hidráulico	Apparecchio di manovra idradinamico
Indicator, Electric	Indicateur électrique	Indicadora eléctrico	Indicatore elettrico
Insulation	Isolement	Aislamiento	Isolamento
Insulated Fish Plate	Eclisse isolé	Brida aislado	Stecca isolata
Insulation or Profile Piece between Rails	Pièce intermédiare isolé de joint	Pieza intermedia aislato de junta	Strato interposto isolata al giunto
Insulated Rail	Rail isolé	Carril aislado	Rotaia isolata
Key Occupation System, Tyer's Patent	Appareil avec clé occupier le voie unique, Brevété Tyer	Aparato con clave ocupar la via simple, Patente Tyer	Apparecchio con chiáve possedére la via singolare, Patente Tyer
Key Token Instrument, Tyer's Patent	Appareil de clé pour voié unique, Bréveté Tyer	Aparato de clave para via simple, Patente Tyer	Apparecchio del chiáve per via singolare, Patente Tyer
Lightning Arrestor	Parafoudre	Pararrayos	Parafulmine
Lock and Block	Serrure et Bloc	Cierre aun Block	Serratura e Blocco
Lock, Electric	Serrure électrique	Cierre elétrica	Serratura elettrico
Low-Pressure Pneumatic Power Plant	Appareil de manœuvre à air comprimé à basse pression	Aparato de maniobra de aire comprimido á baja presión	Apparecchio di manovra ad aria compressa a bassa pressione
Motor	Moteur	Motor	Motore

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Pneumatic Power Plant	Appareil de manœuvre à air comprimé	Aparato de maniobra de aire comprimido	Apparecchio di manovra ad aria compressa
Pouch for Tablet	Récepteur pour Tablette	Receptor para Tableta	Ricevitore per Tavoletta
Power Signalling	Signalisation par force	Movimento de Señales por fuerza	Movimento di Segnali per fórza
Rail Bond	Etrièr de connexion des Rails	Estribo de conexión para carriles	Staffa di collegamento delle rotaie
Relay	Relais	Relais	Relais
Repeater, Signal Arm	Signal de replique pour Bras	Señal de réplica para brazo	Segnale di replica per braccio
Repeater, Signal Arm and Light	Signal de replique pour Bras et Lumière	Señal de réplica para brazo y luz	Segnale di replica per braccio e lúme
Repeater, Signal Light	Signal de replique pour Lumière de Signal	Señal de réplica para luz de Señal	Segnale di replica per lúme del Segnale
Repeater, Signal Slot	Signal de replique pour bras de consentement	Señal de réplica para brazo de consentimiento	Segnale di replica per braccio di consenso
Signal Repeater	Signal de replique	Señal de réplica	Segnale di replica
Signal Replacer	Appareil replacer le Signal	Aparato reemplazar le señal	Apparecchio rilogáre lo segnale
Staff Catcher	Appareil recepteur du bâton	Aparato receptor del bastón	Apparecchio ricevitore del bastone
Staff Instrument	Appareil à bâtons	Aparato para bastones	Apparcecchio per bastone pilota
Switching-out Apparatus	Appareil à fermer le circuit	Aparato cerrar de circuito	Apparecchio chiúdere di circuito
Tablet	Tablette	Tableta	Tavoletta
Tablet Catcher	Appareil récepteur de la tablette	Aparato receptor de la tableta	Apparecchio ricevitore del tavoletta

ENGLISH.	FRENCH.	SPANISH.	ITALIAN.
Tablet Instrument Absolute, Tyer's System	Appareil Tablette pour Bloc absolu, Tyer pour voie unique	Aparato Tableta para Block absoluto, Tyer, para via simple	Apparecchio Tavoletta pilota per Blocco assoluto Tyer, per via unico
Tablet Instrument—Crossing, Tyer's System	Appareil Tablette pour Bloc à passage traversée, Tyer, pour voie unique	Aparato Tableta para Block enclavamient crucero, Tyer, para via simple	Apparecchio Tavolette pilota per Blocco traversa, Tyer, per via único
Tablet Instrument—Intermediate, Tyer's System	Appareil Tablette pour Bloc intermédiare, Tyer, pour voie unique	Aparato Tableta para Block intermedio, Tyer, para via simple	Apparecchio Tavoletta pilota per, Blocco intermedia, Tyer per via único
Tablet Instrument—Permissive or Absolute, Tyer's System	Appareil Tablette pour Bloc permissifou absolu, Tyer, pour voie unique	Aparato Tableta para Block permissivo ó absoluto, Tyer, para via simple	Apparecchio Tavoletta pilota per Blocco permissivo od assoluto, Tyer, per via único
Telegraph Instrument—Single Needle	Appareil télégraphique à cadran simple	Aparato telegráfico de cuadrante simple	Telegrafo con apparecchio ad ago único
Telephone	Téléphone	Teléfono	Telefono
Track Circuit	Circuit de la voie	Circuito de la via	Circuito del binario
Train Control—Automatic	Contrôl automatique du Train	Comprobación automática del tren	Controllóre automatico di treno
Train Describer	Appareil décrire le train	Aparato describir el tren	Apparecchio descrívere lo treno
Train Staff	Bâton pour Train	Bastone para tren	Bastone pilota per treno

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